004

SCIENCE DEVELOPMENT AND TRANSFER SERIES

Ontario

Ecology and Management of Eastern White Pine

in the Lake Abitibi (3E) and Lake Temagami (4E) Ecoregions of Ontario

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by

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2008

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Northeast Science and Information
Ontario Ministry of Natural Resources
P.O. Bag 3020, Hwy 101 East
South Porcupine, Ontario
Canada PON 1H0

Science Development and Transfer • Ontario Ministry of Natural Resources

Library and Archives Canada Cataloguing in Publication Data

Main entry under title:
Ecology and management of white pine in the Lake Abitibi (3E) and Lake Temagami (4E) ecoregions of Ontario

(Science development and transfer series; no. 004)
Includes bibliographical references.
Available also on the Internet.
ISBN 978-1-4249-7011-7

1. White pine—Ecology—Abitibi, Lake Region (Ont. and Québec). 2. White pine—Ecology—Ontario—Temagami, Lake Region. 3. Forest ecology—Abitibi, Lake Region (Ont. and Québec). 4. Forest ecology—Ontario—Temagami, Lake Region. 5. Forest management—Abitibi, Lake Region (Ont. and Québec). 6. Forest management—Ontario—Temagami, Lake Region. I. Latremouille, C. II. Ontario Forest Research Institute. II. Series.

SD397.P65 E26 2008 634.9'75120971314 C2008-964014-4

Printed in Ontario, Canada

Single copies of this publication are available from:

Ontario Forest Research Institute
Ministry of Natural Resources
1235 Queen Street East
Sault Ste. Marie, ON
Canada P6A 2E5

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Abstract

This technical report provides detailed information that supports the *White Pine in the Lake Abitibi and Lake Temagami Ecoregions of Ontario* public report that is part of the Ontario Ministry of Natural Resources' *State of Resources Reporting* series. A general description of the climate, physiography, geology, soils, and vegetation of the Lake Abitibi (3E) and Lake Temagami (4E) ecoregions of northeastern Ontario is followed by a brief review of the ecology and silvics of white pine (*Pinus strobus* L.), with special reference to northeastern Ontario. The role of white pine in the settlement and economic development of Ontario, as well as the parallel evolution of forest management policy over the past 200 years, illustrates how the white pine forest resource was systematically depleted and degraded. This historical legacy is reflected in the current distribution, composition, and structure of white and red pine (*Pinus resinosa* Ait.) forests in northeastern Ontario. The current state of these forests, particularly in Ecoregion 3E at the northern limit of the natural range of white pine in Ontario, presents many challenges to management of this species for its many economic, social, and ecological values. Ontario's white pine forests are now managed according to the principle of conservation of biodiversity adopted under the *Crown Forest Sustainability Act*, using harvesting practices that emulate natural disturbances. Science-based forest policies and guidelines provide management direction for white pine to sustainable forest licensees operating on Crown forests. Based on their relative effectiveness in meeting a range of site- and stand-specific management objectives, including restoration and management for old growth white and red pine forests, a variety of silvicultural options are used to manage white pine in northeastern Ontario. A combination of monitoring, forest research and technology development, and an adaptive management approach is intended to improve the tools and silvicultural effectiveness of forest operations directed towards white pine management. Model simulations project that the use of current selected management practices will increase the total amount of white and red pine forest in both ecoregions 3E and 4E. By comparison, a short-term increase in the area of old growth white and red pine forests is forecast, followed by a decrease in both ecoregions. Future white pine wood supply is also projected to decrease because white pine forests are being increasingly managed for ecological and social values and because the final removal harvest of older shelterwoods that are not satisfactorily regenerating will be delayed. Continued development and application of improved operational management practices and increased silvicultural investment in regeneration of white and red pine forests are needed to address these projected declines in old growth forest area and wood supply.

Resumé

Ce rapport technique, publié à l'appui du rapport sur l'état des ressources portant sur le pin blanc dans les régions du lac Abitibi et du lac Temagami, renferme un examen détaillé de l'information sur laquelle repose le rapport sur l'état des ressources destiné au public. Il présente une description générale du climat, de la géographie physique, de la géologie, des sols et de la végétation des écorégions du lac Abitibi (3E) et du lac Temagami (4E), suivie d'un bref examen de l'écologie et de l'écologie forestière du pin blanc (Pinus strobus L.) dans le contexte particulier du Nord-Est de l'Ontario. Les auteurs du rapport expliquent le rôle que le pin blanc a joué dans l'établissement et le développement économique de l'Ontario ainsi que l'évolution parallèle des politiques forestières au cours des deux derniers siècles, et illustrent comment ces facteurs ont contribué à l'épuisement et à la dégradation systématiques du pin blanc en tant que ressource forestière. Ce patrimoine historique se reflète dans la distribution, la composition et la structure actuelles des forêts de pin blanc et de pin rouge dans le Nord-Est de l'Ontario. L'état actuel de ces forêts, surtout dans l'écorégion 3E à la limite nord de l'aire de répartition naturelle du pin blanc en Ontario, pose de nombreux obstacles à la gestion visant à développer les nombreuses valeurs économiques et sociales de cette espèce. À l'heure actuelle, la gestion des forêts de pin blanc se fonde sur le principe de la conservation de la biodiversité adopté par la Loi de 1994 sur la durabilité des forêts de la Couronne. Elle fait appel à des techniques de récolte qui imitent les perturbations naturelles. La gestion du pin blanc effectuée par les titulaires de permis d'aménagement forestier durable qui exploitent les forêts de la Couronne est guidée par des politiques et des lignes directrices à fondement scientifique. Une variété de méthodes sylvicoles sont employées pour gérer le pin blanc dans le Nord-Est de l'Ontario, selon l'efficacité avec laquelle elles permettent de réaliser divers objectifs de gestion liés à des sites et à des peuplements précis, y compris la restauration et la gestion des forêts anciennes de pin blanc et de pin rouge. La surveillance, la recherche forestière, le développement de technologies et la gestion adaptative assurent l'amélioration des outils ainsi que l'efficacité sylvicole des opérations forestières axées sur la gestion du pin blanc. Selon les modèles de simulation, l'adoption de certaines pratiques de gestion permettra d'accroître la superficie des forêts de pin blanc et de pin rouge dans les écorégions 3E et 4E. Les prévisions, par comparaison, laissent entrevoir une augmentation à court terme de la superficie des forêts anciennes de pin blanc et de pin rouge dans ces deux régions, suivie d'une diminution. On prévoit également une diminution de l'approvisionnement en pin blanc dans les années à venir parce que les forêts de pin blanc sont de plus en plus aménagées en fonction de leur valeur écologique et sociale et que la récolte finale des abris plus anciens qui ne se régénèrent pas de manière satisfaisante sera retardée. Il est essentiel de continuer d'élaborer et de mettre en œuvre de meilleures pratiques de gestion opérationnelle et de faire plus d'investissements sylvicoles dans la régénération des forêts de pin blanc et de pin rouge pour éviter la diminution prévue de la superficie des forêts anciennes et de l'approvisionnement en bois.

Acknowledgements

We thank Larry Watkins, Don Higgs, Mike Malek, John Copeland, and Steve Banducci for providing Ontario Ministry of Natural Resources (MNR) data and assistance with their interpretation and presentation. We also thank Greg Lucking and Chad Anderson for early guidance on the report. Andree Morneault, Ken Armson, Darwin Burgess, Tom Noland, Dave Etheridge, Mark Kuhlberg, Bill Dalton, Colin Templeton, and Betty Vankerkhof provided thoughtful, thorough scientific and technical reviews that greatly improved the document. Lisa Buse provided valuable editorial guidance and Trudy Vaittinen assisted with the figures and produced the report.

Contents

1 Introduction

Eastern white pine (*Pinus strobus* L.) was critical to the early socio-economic development of Ontario (Morse 1984, Aird 1985, McNutt 1985) and continues to be highly prized for its ecological, economic, and social values. Natural and anthropogenic factors such as past management practices, the introduction of blister rust (*Cronartium ribicola* J.C. Fisch.) to North America in the early 20th century, and institutional fire suppression have shaped the current distribution and condition of the white pine resource throughout its native range[1] as well as in Ontario. The specific regeneration requirements, inherently slow initial growth rate, and susceptibility to damage from blister rust and the white pine weevil (*Pissodes strobi* Peck) make the management of white pine very challenging. This is particularly true where white pine approaches the northern limit of its range. Here, the cooler climate, smaller populations that may produce low amounts of viable seed, and higher risk of blister rust infection may limit the establishment and growth of this tree species more than in more southerly areas. In addition, knowledge about white pine, both scientific and practical, is largely centred in the heart of its range where it is most abundant (in Ontario, for example, in the Ottawa River valley and Algonquin Provincial Park). Recent research and operational efforts focusing on management of white pine at the northern edge of its distribution will increase the breadth of information and experiential knowledge needed by forest managers to maintain and restore white pine forests on this landscape.

This technical report provides detailed information in support of the following public report in the Ontario Ministry of Natural Resources' (MNR) *State of the Resources Reporting* series: *White Pine in the Lake Abitibi and Lake Temagami Ecoregions of Ontario.*[2] It presents a brief review of the ecology of white pine, with special reference to the Lake Abitibi (3E) and Lake Temagami (4E) ecoregions of northeastern Ontario. As well, it provides a detailed presentation and discussion of provincial data on the current status and management of this resource. An overview of the climate, physiography, geology, soils, ecology, and ecological values associated with white pine forests in this region is followed by a review of the historical social and economic importance of white pine to both the province and the region. The manner in which European settlement and the historical development of Ontario shaped the current extent, composition, structure, condition, and management of the white pine resource in the region is discussed. The policies and management practices presently in use, as well as current challenges to white pine management in these ecoregions are summarized. The report concludes with a discussion of modelling efforts to compare the effects of current selected management scenarios on the future extent of white pine forests and associated wood supply.

Information in this report was gathered from a number of sources including Ontario's Forest Resource Inventory (FRI),[3] past and current approved forest management plans (FMP),[4] annual reports on forest management,[5] and independent forest audits (IFA)[6] of sustainable forest license (SFL)[7] holders operating in ecoregions 3E and 4E. Compiling and presenting data for this report was complicated by several factors. One was the difference between the geographic boundaries of ecoregions 3E and 4E relative to that of MNR's administrative Northeast Region. The region contains 21 forest management units (FMU), which are geographic planning areas managed by individual forest companies under SFLs.[8] In some cases these FMUs include area from both ecoregions 3E and 4E and/or include area outside these ecoregions. Since MNR's forest statistics are grouped by FMU, the values (e.g., annual volume of white pine harvested) had to be normalized for the proportional volume of white pine within individual ecoregions. Throughout the report, every effort has

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[1] Eastern white pine's native range extends north from Newfoundland to southeastern Manitoba and south to northern Georgia (Wendel and Smith 1990).

[2] Ontario Ministry of Natural Resources. White pine in the Lake Abitibi and Lake Temagami ecoregions of Ontario. Document will be available online at: http://www.mnr.gov.on.ca/en/Business/SORR/index.html.

[3] http://www.mnr.gov.on.ca/en/Business/Forests/2ColumnSubPage/199556.html

[4] Forest management plans applicable to forest management units within ecoregions 3E and 4E are available for public viewing at MNR's Northeast Region office near Timmins: Ontario Government Complex, 5520 Highway 101 East, South Porcupine, ON.

[5] http://www.mnr.gov.on.ca/en/Business/Forests/Publication/MNR_E000163P.html

[6] http://www.mnr.gov.on.ca/en/Business/Forests/1ColumnSubPage/STEL02_167055.html

[7] http://www.mnr.gov.on.ca/en/Business/Forests/1ColumnSubPage/STEL02_167461.html

[8] At the time of writing, the Temagami Forest Management Unit in Ecoregion 4E is managed by the Crown under a management plan produced by the OMNR. This area is designated as a Crown Management Unit but operates similarly to an SFL. For the sake of simplicity, the entities responsible for management planning on the forest management units in ecoregions 3E and 4E are generically referred to as "SFL holders".

been made to clearly define the geographic source of data, statistics, and other information reported. Another complicating factor was that data derived from past and current FRI information were sometimes constrained by classification of area and volume of white pine into discrete provincial forest types. As a result, in some cases the white pine and red pine (*Pinus resinosa* Ait.) forest type (PRW) is reported on in lieu of specific discussion of white pine forests. Finally, historical information on harvest levels was often combined for white pine and red pine, precluding specific discussion of the effects of early, widespread logging of white pine forests. Throughout this report, for this forest type we refer to white and red pine (inferring they cannot be distinguished).

Provincial reviews of the status of Ontario's forests are available in the *Forest Resources of Ontario*[9] and Ontario's *State of the Forest* (OMNR 2007b) reports.[10] Those seeking additional readings on white pine and Ontario's forests are directed to the work of Morse (1984), Aird (1985), and Armson (2001). Discussions of white pine management issues are available in the proceedings of several workshops and symposia (Cameron 1978, Sullivan et al. 1985, Funk 1986, Stine and Baughman 1992).[11] For detailed information about the forestry practices used in white pine forests in Ontario, the silviculture guide for Great Lakes–St. Lawrence (GLSL) conifers is recommended (OMNR 1998a).

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[9] http://www.mnr.gov.on.ca/en/Business/Forests/Publication/MNR_E005106P.html

[10] http://www.mnr.gov.on.ca/en/Business/Forests/Publication/196959.html

[11] Also see special edition of The Forestry Chronicle, volume 70, number 4 (1994) that presents selected contributions to the Red and White Symposium held in Chalk River, ON in 1993.

2 The geographical context

The Lake Abitibi (3E) and Lake Temagami (4E) ecoregions are located in northeastern Ontario and cover 14% (13.8 million ha) and 4% (4 million ha) of the province, respectively (Figure 1) (Crins et al. 2008). These ecoregions are both part of the larger Ontario Shield Ecozone as they share the same bedrock geology but differ in the range and pattern of climatic variables. The climate of both ecoregions is generally classified as humid, cool, and continental, with short, warm summers and long, cold, snowy winters (Chapman and Thomas 1968). Mean annual temperature and mean growing season length increase in a southerly direction, while mean annual and summer precipitation are roughly similar between ecoregions. These ecoregional differences in climate influence vegetation type, rate of soil formation, and ecosystem processes. Soils in these ecoregions were formed after the Laurentian ice sheet retreated from the area some 12,000 to 7,000 years ago and on a geological time scale are reatively young. Soils are mostly underlain by very old, hard and acidic, granitic and gneissic bedrock (Crins et al. 2008).

2.1 Ecoregion 3E – Lake Abitibi

Soils in Ecoregion 3E are relatively younger than those in Ecoregion 4E as they were deglaciated more recently. Based on its surficial geology, Ecoregion 3E can be divided into two areas. In the northeast, the Clay Belt is a glacial lake formation of deep, fine-textured soils, generally poorly drained and overlain by varying depths of organic matter (OMNR 2003b). Organic soils and peatlands make up about 50% of the Clay Belt section of Ecoregion 3E, which also supports luvisols and gleysols. The rest of the ecoregion is characterized by acidic, coarse-textured podzols, and has more variable, steep terrain with rock outcrops that have little or no soil scattered amongst areas of deeper, well drained soils (OMNR 2003b). Organic soils and peatlands make up about 50% of the Clay Belt section of Ecoregion 3E, which also supports luvisols and gleysols (OMNR 2003b, Crins et al. 2008).

Figure 1. Location of the Lake Abitibi (3E) and Lake Temagami (4E) ecoregions of Ontario.

Ecoregion 3E is dominated by black spruce (*Picea mariana* (Mill.) BSP), trembling aspen (*Populus tremuloides* Michx.), jack pine (*Pinus banksiana* Lamb.), white birch (*Betula papyrifera* Marsh.), balsam fir (*Abies balsamea* L.), and white spruce (*Picea glauca* (Moench) Voss) (Rowe 1972, Crins et al. 2008) (Table 1). Less common species include white pine, red pine, eastern white cedar (*Thuja occidentalis* L.), eastern larch (*Larix laricina* (Du Roi) K. Koch), red maple (*Acer rubrum* L.), sugar maple (*Acer saccharum* Marsh.), yellow birch (*Betula alleghaniensis* Britt.), and balsam poplar (*Populus balsamifera* L.). White pine is a minor component of forests in Ecoregion 3E and is often found growing with red pine in small, isolated populations. White pine stands in Ecoregion 3E tend to be small relative to those in Ecoregion 4E, and are generally confined to protected, relatively warmer and drier microsites, such as sandy ridges, along lake shores and river banks, and on shallow to moderately deep tills in areas with a rugged and broken topography (Haddow 1948, Perera and Baldwin 1993, Crins et al. 2008).

White pine is relatively infrequent in Ecoregion 3E because it is at the northernmost extent of its current natural range (Haddow 1948). This northern distribution limit is apparently controlled by the interaction between climatic factors (e.g., frost-free period) and fire disturbance, with more frequent, stand-replacing fires to the north and surrounding area favouring jack pine and preventing further northward range expansion of white pine (Haddow 1948, Stiell 1978, Engelmark et al. 2000).

The northernmost white pine populations in Ontario are thought to be remnants of the forests that covered this region 3,000 to 7,000 years ago when the climate was warmer and drier, and wildfires, particularly surface fires, may have been more frequent (Haddow 1948, Terasmae and Anderson 1970, Holla and Knowles 1988, Liu 1990). At this time, white pine may have grown as far north as James Bay (Terasmae and Anderson 1970). As the climate became cooler and moister, beginning about 3,000 years ago, the range of white pine and associated

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tree species shifted south in keeping with their climatic requirements (Jacobson 1979). This shift towards a cooler, wetter climate corresponded with decreased abundance of white pine across North America (Jacobson and Dieffenbacher-Krall 1995).

Wildfire is the predominant natural disturbance agent in this ecoregion, although spruce budworm and forest tent caterpillar are also responsible for large-scale cyclic forest disturbances (Van Sleeuwen 2006, Crins et al. 2008). Fire frequency and intensity vary greatly in this ecoregion. Large, high intensity, stand-replacing crown fires that consume 80% or more of the canopy, or high intensity surface fires are characteristic of upland conifer forests. The mean fire cycle[12] of upland jack pine and black spruce forests ranges from 36 to 187 years (Van Sleeuwen 2006). Stand-replacing fires are less frequent in other forest types and fire intensity varies more. For example, the stand-replacing fire cycle in conifer-dominated forests containing white and red pine in Ecoregion 3E is thought to be 36 to 258 years on average (Van Sleeuwen 2006). Mixedwood forests and hardwood-dominated forests are less flammable and burn less often and at lower intensity, with stand-replacing fires occurring every 63 to 2,700 years (Van Sleeuwen 2006). Fire cycles of 150 to 6,000 years are characteristic of lowland conifer forests of the Clay Belt (Van Sleeuwen 2006, Crins et al. 2008). In Ecoregion 3E, the average fire cycle has been estimated at 531 to 569 years for the era of active fire suppression (Bridge 2001, Carleton 2003).

***Table 1**. Average tree species composition of ecoregions 3E and 4E, expressed as percent contribution to total wood volume.*[13]

Species composition	
Ecoregion 3E	**Ecoregion 4E**
Black spruce (43%)	Trembling aspen (20%)
Trembling aspen (28%)	White birch (18%)
Jack pine (12%)	Jack pine (17%)
White birch (9%)	Black spruce (13%)
Balsam fir (3%)	White pine (10%)
White spruce (3%)	Sugar maple (5%)
Eastern white cedar (2%)	White spruce (4%)
Eastern larch (1%)	Red maple (3%)
Red maple (<1%)	Yellow birch (3%)
White pine (<1%)	Balsam fir (3%)
Balsam poplar (<1%)	Red pine (3%)
Sugar maple (<1%)	Eastern white cedar (2%)
Yellow birch (<1%)	Red oak (<1%)

2.2 Ecoregion 4E – Lake Temagami

The climate of Ecoregion 4E is warmer than that of Ecoregion 3E, with comparatively higher mean annual winter and summer temperatures and a longer growing season (Chapman and Thomas 1968). The amount of precipitation is similar across Ecoregion 4E, except at the east end of Lake Superior where it increases slightly (OMNR 2003b). Soils in this ecoregion are slightly older compared to those of Ecoregion 3E due to its earlier deglaciation. The "Little Clay Belt" in the northeast is wetter, with more fertile soils underlain by limestone bedrock. This higher fertility contributed to the historical agricultural development of this area. Soils of the Little Clay Belt are usually luvisols. Rock outcrops and coarse-textured podzols are abundant in the remainder of this ecoregion, with gleysols and brunisols also common (Crins et al. 2008). The terrain is more broken than in Ecoregion 3E, with abundant north-south flowing river systems (OMNR 2003b).

Ecoregion 4E is characterized by a tree species composition that is transitional between the boreal forest region in Ecoregion 3E to the north and GLSL forest region to the south (Rowe 1972). In this ecoregion, the more southern tree species, such as white and red pine, sugar maple, red maple, yellow birch, and red oak (*Quercus rubra* L.), are more abundant (Rowe 1972) (Table 1). The warmer climate and natural fire cycle in Ecoregion 4E are favourable for the establishment and growth of white pine and therefore its distribution is less restricted than in Ecoregion 3E (Engelmark et al. 2000). White pine increases in abundance in a southward direction and is found primarily on rocky outcrops and drier sites with sandy, moderately fertile soils (OMNR 2003b). White pine and mixed white and red pine stands tend to be larger in Ecoregion 4E than in 3E (Perera and Baldwin 1993).

Wildfire is also the primary form of natural disturbance in Ecoregion 4E and varies regionally in frequency and intensity (Crins et al. 2008). In upland boreal conifer and mixedwood forests, stand-replacing fires are common, with an estimated fire cycle of 50 to 210 years (Van Sleeuwen 2006, Crins et al. 2008). A fire regime of relatively frequent, low intensity fires (i.e., 20-40 years), coupled with infrequent, high intensity stand-replacing fires (i.e., 150 to 300 years) is more common to Ecoregion 4E, and favoured the establishment and perpetuation of white pine- and red pine-dominated forests (Frelich 2002). Tolerant hardwood and lowland conifer and hardwood forests are characterized by lower intensity fires and a fire cycle of 150 to 6000 years (Van Sleeuwen 2006, Crins et al. 2008). The fire cycle in Ecoregion 4E in the era of fire suppression was estimated at 315 to 341 years (Bridge 2001, Carleton 2003).

[12] The fire cycle is defined as the period of time needed to burn an area equal to some area of interest, and is equivalent to a fire rotation (Van Sleeuwen 2006).

[13] Data obtained by applying Plonski's normal yield tables (Plonski 1981) to species composition and stocking data from the FRI compiled for the *State of the Forest Report 2006* (OMNR 2007b).

3 Ecology and silvics of white pine

3.1 Soils

White pine occurs on many soil types, but is most common and competitive on relatively dry, infertile soils with high percentages of sand and an acidic pH (Stiell 1978, Iverson et al. 1999). On these soils, the abundance, growth rate, and competition from more mesophytic, nutrient-demanding species is greatly reduced, favouring white pine (Stiell 1978, Wendel and Smith 1990, Abrams 2001). White pine grows slowly or is absent from poorly drained, clay soils in Ontario where it is replaced by black spruce, white spruce, and larch, and on dry, coarse-textured soils where it is replaced by jack pine and red pine. Best growth occurs on fresh to moist, well drained soils, but white pine occupies sites with a broad range of moisture conditions (Stiell 1978, Wendel and Smith 1990). Sites with finer-textured soils of higher fertility can be highly productive but only where competition is controlled (Stiell 1978). This wide site adaptability of white pine is linked to its intermediate water and nutrient requirements relative to other tree species and its expansive, deeply penetrating root system that also improves its wind stability (Wendel and Smith 1990, OMNR 1998a). Its extensive lateral root system allows it to access localized pockets of deep soil when growing in shallow soils overlying bedrock that are common in the Ontario Shield Ecozone (Horton and Bedell 1960, Brown and Lacate 1961, OMNR 1998a).

3.2 Light

White pine is intermediate in shade tolerance and becomes established and grows best under a partial canopy of existing stands (Wendel and Smith 1990, Burgess and Wetzel 2002). For white pine regeneration, competitive height growth rates require >25% of full sunlight and maximum height growth occurs when light levels are >45% of full sunlight (Logan 1966, Messier et al. 1999). Maximum diameter and total dry mass of white pine seedlings are attained under full sunlight (Logan 1966). Because of the comparatively slow initial height growth rate of mid-tolerant species, understory white pine is often overtopped and suppressed by faster growing shade intolerant woody and herbaceous species, especially on more open, productive (and competitive) sites (Wendel et al. 1990). Under very low light (<1% sunlight) radial growth of white pine is very slow but at 10% sunlight it is intermediate (Pacala et al. 1994). Although early white pine seedling and sapling survival requires 5 to 10% of full sunlight, light requirements for survival increase with tree size (Rudolf 1950, Wendel and Smith 1990, Messier et al. 1999, Dovčiak et al. 2001, 2003).

3.3 Natural disturbance dynamics

White pine is a fire-dependent species, capable of colonizing recently burned sites where the litter layer has been consumed and competing vegetation reduced (McRae et al. 1994, OMNR 1998a, Frelich 2002). The natural fire regime of white pine is relatively complex, consisting of infrequent stand-replacing fire coupled with more frequent, low intensity surface fires (Frelich 2002) (Figure 2). Depending on the specific regional fire regime and soil type, several successional pathways have been proposed for the various forest types containing white pine (Abrams 2001, Frelich 2002). Results of research in the GLSL forests of eastern North America indicate that pre-settlement white pine-dominated forests were subject to stand-replacing, high intensity wildfire on an average 130- to 300-year cycle, with low intensity surface fires occurring every 20 to 40 years (Frelich 2002, Van Sleeuwen 2006). Jack pine, black spruce, aspen, and white birch dominate stands where crown fires occur at intervals shorter than 50 years. In the absence of fire for 200 to 300 years, white pine and red pine stands generally succeed to spruce-fir in the boreal forest and to tolerant hardwoods in the GLSL forest (Heinselman 1981, Carleton et al. 1996, Frelich 2002, Van Sleeuwen 2006).

Figure 2. *Low intensity surface fire in a white pine stand near Sturgeon Falls, ON. (Photo by F. Pinto)*

Small, localized white pine stands can be maintained where the regional fire cycle is shorter and more typical of fire-adapted upland boreal conifer forest types dominated by jack pine and black spruce (Frelich 2002). In Ontario and Quebec, at the more northern limits of its range in the boreal forest region, small white pine populations often occur on rocky outcrops, islands, lakeshores, peninsulas, and river banks (Haddow 1948, Holla and Knowles 1988, Englemark et al. 2000). These locations are less flammable and provide refuges from the more frequent, stand-replacing fires that affect the surrounding landscape. Rock outcrops have little fuel and are less likely to experience stand-replacing fire. Areas around lakes and rivers are also somewhat protected from severe fires because of their more humid microclimate and vegetation that has higher moisture content during periodic drought. The many small lakes in northern Ontario may also act as natural fire breaks, further altering the fire regime and favouring the dominance of white pine in localized pockets.

Mortality of white pine following fire depends primarily on the percentage of crown scorch (i.e., heat damage from hot convective gases) sustained (Van Wagner 1973). White pine trees with less than 50% crown scorch typically survive and those with 75% scorch have a 50% probability of survival (Methven 1971). Lethal crown scorch occurs at temperatures above about 60°C, and height of crown scorch varies with fire intensity (Van Wagner 1973). Complete stem girdling due to heat damage to cambial tissues of the lower stem also results in mortality. Bark thickness increases with stem diameter and is correlated with probability of cambial damage, with white pine survival following surface fires increasing with increasing stem diameter (Harmon 1984, Hengst and Dawson 1994). As a result of these two fire resistance traits, larger, older white pine typically survive low- to moderate-intensity surface fire due to their thick insulating bark, branch-free lower boles (i.e., low live crown ratio and reduced crown scorch), and deep rooting habit (Van Wagner and Methven 1978, Olson and Weyrick 1987). These features also allow a few individual trees to survive higher intensity, stand-replacing fires.

A primary successional pathway for white pine forests in the Great Lakes region of the United States is described as follows: Following severe fire, surviving white pine canopy trees and others in adjacent, undisturbed areas provide a source of seed for regeneration. Peak recruitment of pine occurs for 20 to 40 years after these fires beneath the established canopy of shade-intolerant tree species (jack pine, aspen, white birch) that rapidly colonize the burned site. White pine regeneration grows well in the moderately shaded understory of these open-crowned species and gradually recruits into the overstory canopy as gaps form when the shade-intolerant species begin to die (Frelich 2002). Relatively frequent low-intensity surface fires burn away the litter layer, periodically creating seedbed for new cohorts of pine regeneration and reducing the abundance of any invading, shade-tolerant species in the understory (Methven and Murray 1974, Van Wagner and Methven 1978). Although a proportion of the younger pine regeneration are also killed by these fires, the survivors benefit from the resulting increase in light and decrease in understory competition.

Where stand-replacing fire occurred every 150 to 300 years, this successional cycle was repeated, perpetuating white pine-dominated stands as the climax forest type (Frelich 2002). Where these fires occurred at longer intervals (e.g., 400 to 600 years), these ecosystems were maintained only where periodic low intensity fire occurred (Methven and Murray 1974, Van Wagner and Methven 1978, Frelich 2002). This disturbance regime gave rise to multi-aged, old growth white pine stands (Tester et al. 1997, Frelich 2002). Where low intensity fire did not occur, these forests succeeded to more shade-tolerant, less fire-resistant mixedwood forest types.

3.4 Seed production, seedling establishment, and stand development

White pine may produce seed as early as 15 years of age but peak seed production occurs between 50 and 150 years (Horton and Bedell 1960, Wendel and Smith 1990). Although individuals differ genetically in their reproductive potential, large diameter trees with broad, deep crowns produce the most cones and highest amounts of seed (Wendel and Smith 1990). White pine normally produces small to moderate seed crops each year, but above average, referred to as *bumper*, seed crops in more northern regions occur every 3 to 10 years (Schopmeyer 1974). During these bumper crop years, white pine-dominated stands may produce from 500,000 to 2,000,000 viable seed per hectare (Graber 1970, Heckman et al. 1986). Cones dry, open, and release seed in late summer, and wind dispersal of seed is complete by late fall (Graber 1970). Within forest stands, most seed is dispersed a distance of up to two tree heights from the parent, but may be dispersed up to 200 m from open-grown trees (Wendel and Smith 1990).

Germination and early seedling establishment is optimal on partially shaded sites with moist mineral soil, mineral soil humus mixtures, or burned seedbeds (Smith 1951, Graber 1968, Thomas and Wein 1985a, Kershaw 1993b, Herr et al. 1999). The thermal and hydraulic properties of these seedbeds are more favourable to seed germination and seedling establishment than undisturbed forest floor surface layers. Thick litter layers also impede root penetration to underlying moist mineral soil layers and result in drought-induced mortality of first-year germinants (Smith 1951, Graber 1968, OMNR 1998a). More sheltered microsites are less prone to soil moisture deficits and high temperature stresses that limit white pine seedling establishment (Smith 1951, Thomas and Wein 1985a). As with most conifers, white pine seed remains viable in the soil for less than 16 months (Smith 1951, Thomas and Wein 1985b). As well, small mammals and birds may consume most of the seed produced during non-bumper crop years (Abbott 1961, Graber 1969, Heckman et al. 1986, Duchesne et al. 2000). However, during bumper crop years, even where 98% of seeds are eaten, 10,000 to 40,000 viable seeds per hectare will escape predation, more than enough for high initial stocking of natural regeneration. Hence, successful natural regeneration of this species requires a large population of healthy, seed-producing trees and a bumper crop seed year coinciding with some form of disturbance to create a combination of suitable microsites for germination and a moderately shaded understory environment (OMNR 1998a).

Once established, natural white pine regeneration may reach only 10 to 15 cm in height within 5 years (Horton and Bedell 1960). This is due in part to the comparatively slow relative growth rates of more shade-tolerant species and preferential carbohydrate allocation to root growth during early seedling establishment (Wendel and Smith 1990, Peichl and Arain 2007). White pine requires increasingly higher amounts of light to ensure survival and the height growth necessary to successfully recruit into the developing canopy (Rudolf 1950, Dovčiak et al. 2001, 2003). As a result, although large numbers of white pine seedlings can become established under a closed canopy during above average seed years, they are generally unable to survive in the heavy shade beneath undisturbed conifer stands (Day and Carter 1990, Dovčiak et al. 2001, 2003). Thus, in the absence of disturbance by fire or silvicultural treatments that emulate this disturbance agent white pine forests generally do not perpetuate themselves (Maissurow 1935, Day and Carter 1990, Carleton et al. 1996, Weyenberg et al. 2004). Instead, undisturbed or unmanaged white pine forests typically undergo gradual successional replacement to more shade-tolerant forest types dominated by white spruce, balsam fir, maples, and hardwood shrubs, particularly on more mesic, productive sites (Day and Carter 1990, Wendel and Smith 1990, Carleton et al. 1996, Abrams 2001) (Figure 3) (see Section 3.3).

Under favourable understory conditions, seedling growth increases appreciably at about age 5 (Horton and Bedell 1960, Wendel and Smith 1990). At a height of about 1.5 m (age 8 to 10), white pine seedlings grow 0.3 to 0.4 m per year on average, but can grow as much as 1 m in height and 2.5 cm in diameter per year (Horton and Bedell 1960, Stiell 1978). Vigorous, properly planted seedlings typically have a more rapid rate of early growth than naturally regenerated seedlings (see Section 7.1.3 - *Regeneration*). Stand and site conditions influence tree growth, with growth rates being restricted where competition and stand density are relatively high, soils are shallow, and moisture and nutrients are limiting (Horton and Bedell 1960, Wendel and Smith 1990).

White pine has much higher potential height growth than red pine but, depending on site conditions, does not begin to outgrow it until 40 to 80 years of age (Stiell 1978). By the time they reach 70 years of age, white pine stands out-produce those of all other commercial tree species in Ontario in volume and (potentially)

Figure 3. *Undisturbed white pine stands develop understories dominated by balsam fir and other more shade-tolerant species. (Photo by D. Burgess)*

economic value on favourable sites (medium-textured sandy loams) (Stiell 1978). For example, a 70-year-old white pine stand growing on a rich site (Site Class 1) might contain a gross merchantable wood volume of about 372 $m^3 ha^{-1}$, whereas black spruce, tolerant hardwoods, white birch, jack pine, aspen, and red pine stands would have 146, 158, 187, 238, 365 and 365 $m^3 ha^{-1}$, respectively (Plonski 1981).

White pine is a long-lived tree species that can grow to a relatively large size (Figure 4). White pine trees as old as 450 years have been reported but the life expectancy of individual trees declines significantly after 160 years (Horton and Bedell 1960). Historical reports of trees growing as big as 1.5 m in diameter and 50 m in height are common for better sites (Frothingham 1914, Wendel and Smith 1990, Taylor et al. 2000). Maximum height varies with climatic and soil factors and generally decreases with latitude (Frelich and Reich 2003). Due to this species' superior height growth and maximum attainable size, older white pine trees typically grow above the main tree canopy of associated species, forming "supercanopy" trees (Figure 5). These larger, older white pine trees are important ecological components of both old-growth forests and the second-growth forests being managed today (Rogers and Lindquist 1992, Naylor 1994).

3.5 Uses by wildlife

Many forest-dwelling amphibians, reptiles, birds, and mammals rely on some successional stage of white pine forests to meet one or more of their habitat requirements (Naylor 1994). White pine seed is an important food source for birds and small mammals and is generally preferred over that of other associated coniferous species (Abbott 1962, Cornett et al. 1998, Duchesne et al. 2000, Plucinski and Hunter 2001). Although conifer species are not a preferred browse species of most mammals, white-tailed deer (*Odocoileus virginianus* Zimm.), porcupine (*Erethizon dorsatum* L.), moose (*Alces alces* L.), and snowshoe hare (*Lepus americanus* Erxleben) feed on needles, twigs, or bark of white pine trees and seedlings (Pastor 1992).

Living and dead, standing or fallen trees provide valuable habitat for many wildlife species. Standing trees serve as perching, nesting, roosting, and feeding sites for wildlife, depending on tree species, size, cause of injury or death, state of decay, and location (DeGraaf and Shigo 1985, Rogers and Lindquist 1992). Bald eagles (*Haliaeetus leucocephalus* L.), ospreys (*Pandion haliaetus* L.), and great blue herons (*Ardea herodias* L.) appear to prefer to nest in pine stands near

***Figure 4**. Large, tall white pine trees in (a) Wakami Lake Provincial Park and (b) McLaren Forest Conservation Reserve, ON. (Photos by A. Sheppard and C. Latremouille, respectively)*

Figure 5. *Example of supercanopy white pine trees in Paudash Township about 45 km south of Gogama, ON. (Photo by B. Parker)*

water bodies, while a number of bird species frequently nest in forests with abundant white pine (DeGraaf and Shigo 1985, Rogers and Lindquist 1992, Naylor 1994). Large, standing dead white pine trees in relatively low density areas of white pine and red pine stands were preferred roost sites of male bats (*Myotis* sp.) in central Ontario (Jung et al. 2004). Downed wood provides feeding sites for birds and foraging and denning sites for reptiles, amphibians, and mammals (Harmon et al. 1986, Bellhouse and Naylor 1996). White pine is often a dominant tree species of forest and lake ecotones in Ontario, and the abundant white pine downed wood found in littoral zones of many lakes provides important substrate for many plant and animal species (Guyette and Cole 1999).

The irregular crown structure and comparatively large size of older white pines are particularly important for some wildlife species (DeGraaf and Shigo 1985, Rogers and Lindquist 1992) (Figure 6). Living white pine supercanopy trees, often with dead tops or crowns, are favoured by bald eagles and ospreys, perhaps because they are able to support the weight and size of their large nests (Mathisen 1968, DeGraaf and Shigo 1985, Livingston et al. 1990, Rogers and Lindquist 1992). Despite their general avoidance of pine forests, black bears (*Ursus americanus* Pallas) select large white pine trees as bedding sites and refuge trees, e.g., larger, supercanopy white pine trees often become hollow and provide desirable denning sites (Rogers and Lindquist 1992).

3.6 Damaging agents

3.6.1 Insects and diseases

More than 250 insect species and 110 disease-causing organisms are known to attack white pine but relatively few cause sufficient damage to be of serious concern (Horton and Bedell 1960, Stiell 1978, Wendel and Smith 1990). Several species of sawflies (*Diprion* sp. and *Neodiprion* sp.), the pine root collar weevil (*Hylobius radicus* Buchanan), pine false webworm (*Acantholyda erythrocephalus* L.), pine bark adelgid (*Pineus strobi* (Hartig)), white pine cone beetle (*Conopthorus coniperda* Schw.), red ring rot (*Phellinus pini* (Brot.:Fr.) A. Ames), and Armillaria root rot (*Armillaria ostoyea* (Romagn) Herink) (Wendel and Smith 1990, deGroot et al. 2005) all affect white pine. However, the most serious pathogens are white pine weevil and white pine blister rust. The damage they cause is described briefly here, with in-depth discussion of their life cycle, biology, and silvicultural control options provided in Section 7.1.3.

 

Figure 6. The irregular crown structure and dead tops of larger white pine trees have comparatively high value to wildlife species. (Photos by B. Parker)

White pine weevil

White pine weevil is an insect endemic to North America and found across Canada. Although the weevil will attack many native and exotic conifer species (e.g., Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) Karst.), white pine is its primary natural host in eastern Canada (MacAloney 1930). Weevil attacks are centred on the terminal shoots that are used for oviposition and larval development. Feeding on the cambial tissue by larvae results in girdling and death of the terminal shoot. The length of stem damaged from a single attack generally includes the previous and current year's terminal shoot (2 years height growth), but occasionally 3 to 5 years of height growth are affected (Marty and Mott 1964). The minimum percent loss in annual height growth due to a single weevil attack was estimated at 60 to 70% (MacAloney 1930, Morrow 1965), with repeated weevil attacks reducing total height up to 10 m over a rotation (Brace 1971). The weevil prefers vigorous trees 2 to 6 m tall, with terminal shoots greater than 4 mm in diameter (Sullivan 1961, Gross 1985a). Attacks decline markedly when trees attain a height of 5 m, such that weevil is most prominent in 15- to 20-year-old trees (Belyea and Sullivan 1956). Since terminal shoot diameter increases with light levels, weevil damage is more prominent in pine growing in open environments such as plantations and old fields (Belyea and Sullivan 1956). Although genetic resistance to injury has been noted, it is small relative to the influence of environmental factors (Kriebel 2004).

Degree of weevil damage to white pine varies among individual trees, years, and with site and stand conditions (MacAloney 1930, Rudolf 1950, Marty and Mott 1964, Hodge et al. 1990, Katovich and Morse 1992, Lavallée et al. 1996). Taller, dominant and codominant saplings within a plantation are generally attacked most frequently (Sullivan 1961, Marty and Mott 1964, Patterson and Aizen 1989). A survey of Ontario white pine plantations indicated 50% of stands examined in a given year were affected by weevil, with up to 28% of trees being attacked (Gross 1985a). Weevil damage ranged from 3 to 80% of trees in pure, young (≤30 years) natural and planted white pine stands in the northeastern and Lakes States regions of the United States (MacAloney 1930, Rudolf 1950, Wilkinson 1983). Trees may be repeatedly attacked, with up to 6 weevil injuries per 5 m log found in second-growth white pine stands (Marty and Mott 1964, Brace 1971, Wilkinson 1983, Pubanz et al. 1999).

Injury from this insect rarely results in mortality, but the resulting deformed stems greatly reduce merchantable volume and future wood quality (Waters et al. 1955, Brace 1971, Gross 1985a) (Figure 7). The insect's preference for trees 2 to 6 m tall results in wood quality damage being centred in the valuable first log. For a given tree, loss of volume and quality increases with the number of weevil attacks suffered (Marty and Mott

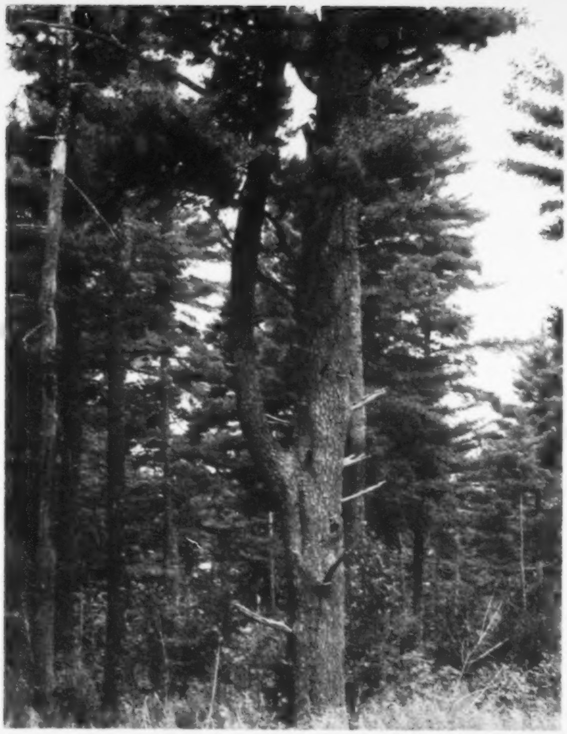

Figure 7. Example of stem deformation in a mature white pine that is typical of white pine weevil injury. (Photo by B. Parker)

1964, Brace 1971). Reduction in merchantable volume may result from loss of merchantable height, diameter, and higher numbers of defects (e.g., loose knots, red rot wood decay, compression wood, cross grain), while lower quality is due to defects that decrease the proportion of higher grade (and value) lumber produced (Waters et al. 1955, Brace 1971). Average merchantable sawlog volume loss for second-growth white pine stands may range from 20 to 60% (Waters et al. 1955, Brace 1971). In trees subject to repeated annual attack, multiple-leadered, globular shaped "shrubs" that have no commercial value can be formed (MacAloney 1930, Belyea and Sullivan 1956).

Blister rust

White pine blister rust is a disease caused by an exotic fungus species introduced to North America from Europe in the early 1900s on white pine planting stock imported to meet domestic reforestation needs (Hunt 2003). The fungus can infect and kill white pine of any age, but mortality is most likely at the seedling stage. Because successful infection depends on specific temperature and moisture conditions, infection levels and resulting mortality rates vary with climatic and physiographic factors that affect the microenvironment of stands and individual white pine (Hodge et al. 1990) (for details see Section 7.1.3). In areas conducive to high infection rates, blister rust can kill >75% of crop trees in a plantation (Hodge et al. 1990, Pitt et al. 2006). Surveys of southern Ontario plantations, where the risk of infection is comparatively low (Gross 1985b), showed infection rates ranging from 0.5 to 26.7% of trees, and averaging 8.8% (Cafley 1958). In 24 young (<25-year-old) white pine plantations in central Ontario, where the infection risk is generally higher, percentage of rust-infected or rust-killed trees ranged from 1.2 to 72.6%, and averaged 21.5% (Haddow 1956).

3.6.2 Wind

White pine can be damaged by high winds through uprooting or stem breakage (Figure 8). The risk of wind damage depends on the interaction of several meteorological and topographic factors; crown, stem, and root attributes; soil factors affecting rooting depth; and stand factors such as age, density, disturbance/treatment history, and species composition (Stathers et al. 1994, Everham and Brokaw 1996, Peterson 2007). These factors vary spatially and with time, complicating the relative ranking of the windfirmness of white pine. Where soil physical properties allow, the fairly deep rooting potential of white pine makes this species windfirm relative to spruce (Stoeckeler and Arbogast 1955, Wendel and Smith 1990). However, in recently thinned stands, occasional severe storms can uproot mature trees (Horton and Bedell 1960, Burgess et al. 2000, Bebber et al. 2005), particularly on shallow, poorly drained soils that reduce rooting depth (Stathers et al. 1994).

Catastrophic wind storms (e.g., hurricanes) cause severe damage to most tree species. The comparatively high level of wind damage to white pine during severe wind events is generally attributed to its large size (Curtis 1943, Foster 1988, Frelich 2002). Older white pine may be more susceptible to wind damage due to infection by wood- and root-rotting pathogens that weaken stems and root systems (Stoeckeler and Arbogast 1955, Webb 1988, Stathers et al. 1994).

3.6.3 Browsing

In some regions, browsing by mammalian herbivores can be a limiting factor for white pine regeneration, particularly in plantations (Rudolf 1950, Pastor 1992, Saunders and Puettmann 1999, Frelich 2002). Generally, significant browse damage to white pine seedlings and trees is localized and occurs in certain areas, during cyclic periods of high herbivore populations, or during seasonal absence of more

Figure 8. White pine trees that were uprooted or broken during a severe wind storm near Mattawa, ON in 2006. (Photo by B. Parker).

desirable browse species (Rudolf 1950, Pastor 1992, Tester et al. 1997). Heavy, repeated browsing of terminal and lateral shoots of white pine seedlings reduces height growth, delays canopy recruitment, and may decrease future wood quality (Pastor 1992, Saunders and Puettmann 1999, Krueger and Puettmann 2004). The dramatic increase in populations of white-tailed deer in parts of the Great Lakes region over the past 50 years have greatly reduced regeneration and canopy recruitment of white pine (Tester et al. 1997, Frelich 2002).

4 Social and economic importance of white pine

4.1 Historical importance

4.1.1 Importance to native people

Native peoples of eastern Canada were largely hunter-gatherers that relied heavily on forests for their livelihood and survival. Prior to European settlement, native people used Canada's forests for traditional camps, portages, spiritual sites, and burial sites. Forests also provided them with food, medicine, fuel, dwellings, utensils, construction materials, and countless other products needed to sustain daily life (Standing Woman and Comer 1996, Aird 2001). Native North Americans also purposefully manipulated the forests with fire to improve habitat for game and the production of natural plant foods (Dey and Guyette 2000, Aird 2001, Nowacki and Abrams 2007). The many resources, or "gifts", provided by nature formed an important part of the spiritual beliefs of Aboriginals and forests were no exception, with trees often being prominent figures in myths and legends. Notably, the strong and majestic white pine was embraced as a spiritual symbol by native peoples inhabiting the eastern Great Lakes region. As an example, the white pine, or *Tree of the Great Peace*, was at the centre of the history and tradition of the confederacy formed by the Five Nations Iroquois of New York state in the mid-15th century (Schroeder 1992, Standing Woman and Comer 1996).

4.1.2 Provincial development of the white pine industry

As stated by naturalist Donald Peattie (1966), "Perhaps no other tree in the world has had so momentous a career" as white pine, and "certainly no other has played so great a role in the life of the people" of Canada. At the time of European settlement, white pine was one of Canada's few natural resources of value for international trade and provided an important early source of capital for an emerging nation. The province of Ontario was blessed with the nation's most abundant and largest extent of high quality white pine (Aird 1985, Armson 2001). In Ontario during the 19th century, the sale of white pine square timber and lumber provided nearly 30% of all revenue collected by the provincial treasury and financed the construction of schools, roads, and other infrastructure, services, and functions provided by the government (Aird 1985).

The value of white and red pine forests as a source of masts and other naval timbers for the Royal British Navy was recognized in the mid-18th century. However, commercial harvest of white and red pine did not begin until the early 1800s with the era of the square timber trade. Centred in the Ottawa and St. Lawrence River valleys, huge rafts containing 2,000 to 4,000 m^3 of square timber were floated to markets in Quebec City for shipment to England (Figure 9). At the peak of the square timber trade, as much as 1 million m^3 of pine were shipped to markets annually.

At this time, the white pine resource was widely viewed as inexhaustible and high-grading – removal of only the large, straight, and defect-free trees suitable for square timber – inevitably led to wasteful practices (Figure 10). Harvested trees that fell short of the stringent quality requirements were left on the ground. The squaring process was also wasteful (Figure 11): As much as 50% of the harvested wood was left to rot on the forest floor (Aird 1985).

By the mid-19th century, the square timber trade was declining and in the Ottawa valley, which had been largely cleared for settlement, commercial stands of white pine were becoming scarce. This provided the impetus for the construction of railroads to harvest previously inaccessible pineries between the Ottawa River and Georgian Bay (Morse 1984, Armson, 2001). During this time, the United States was entering a reconstruction phase after the Civil War (1861-1865), and expansion of settlement into the Great Lakes region required a source of building material to support construction of large population centres such as Chicago, Cleveland, and Milwaukee. The great pineries of Michigan, Wisconsin, and Minnesota were

Figure 9. A raft of white pine and red pine square timber nears completion near Ottawa, ON (circa 1901). (Photo from Armson 2001)

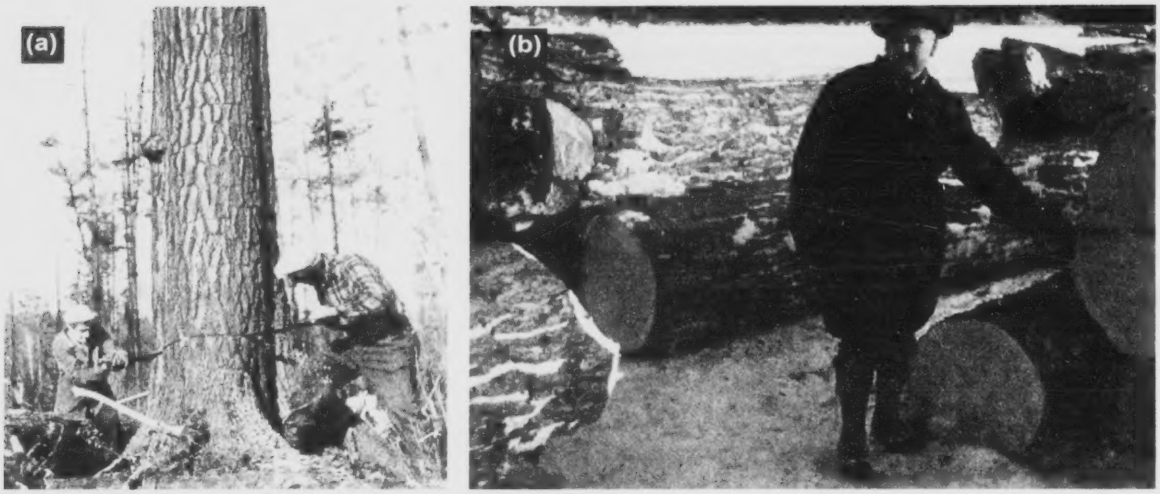

Figure 10. Past harvesting practices often focused on removing the largest, best quality trees. (a) Large, straight white pine being harvested at Flame Lake Camp near Chapleau, ON (1948) and (b) scaling large white pine sawlogs in the 1950s. (Photos from Ontario Dept. Lands Forests and L. Thompson, respectively)

being logged but were insufficient to meet this demand. As a result, the northern U.S. forest industry looked to Ontario's pine forests as an additional source of valuable lumber (ODLF 1967, Epp 2000).

4.1.3 Regional development of the white pine industry

The remote forests of northeastern Ontario were inaccessible to settlers and economic interests for most of the 1800s (Morse 1984) until the Commissioner of Crown lands opened the area north of Georgian Bay to the lumbering industry in 1872 (ODLF 1967). Early demand for forest resources in this region included white and red pine square and waney (i.e., similar to square timber but with edges rounded to increase wood utilization) timbers and sawlogs (ODLF 1967, Morse 1984). The growing scarcity of high quality white and red pine coupled with the decline of the square timber trade led to an increased focus on harvest of sawlogs in this region in the 1880s (ODLF 1964c). White and red pine harvest was first concentrated along lakes and navigable rivers that were used to transport logs to mills and markets[14] (Figure 12). Many pine logs were floated down major tributaries of Georgian Bay, Lake Huron, and Lake Superior and transported to mills and markets in Michigan, Minnesota, and Wisconsin (ODLF 1967, Aird 1985).

Figure 11. Squaring of white pine timber was a wasteful process as much sound wood was left on the forest floor. (Photo from Ontario Ministry of Natural Resources)

While rivers provided an inexpensive means of transporting pine to markets, their use was limited to the short ice-free seasons (Morse 1984, Armson and McLeod 2007). The many narrow rivers and shallow lakes of northern Ontario also made transport of pine logs more difficult than was the case in the Ottawa Valley. In the late 1880s, an amphibious, steam powered tug boat, the "alligator", was designed that could portage itself from lake to lake to move logs to mills (Trinnell 1998, Armson and McLeod 2007). While on water, logs were pulled slowly across lakes in booms using the boat's winch and more than 1,700 m of steel cable. Use of this method to move logs overland between lakes was costly, slow, and arduous work.

[14] For example, logging seldom extended more than 15 km from the shore of Lake Timiskaming, ON (Temagami Forest FMP 2004).

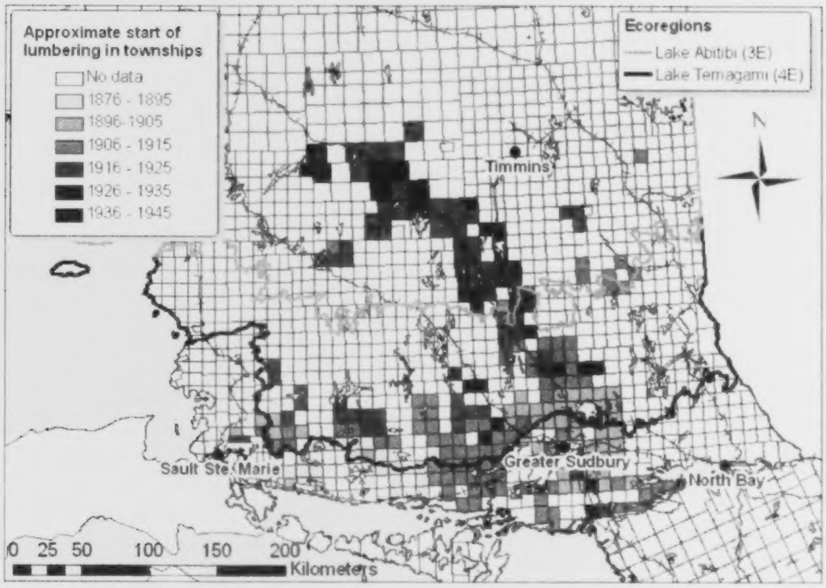

Figure 12. *Approximate start of white pine and red pine lumbering in northeastern Ontario (see Appendix 1). Logging started along the shores of Lakes Superior, Huron, and Nipissing and moved futher inland following expansion of railroads.*

While feasible, log transport via water was slow and was increasingly replaced by railroads to access and facilitate transport from the unexploited pineries in the north (Figure 13). Driven by commercial interests in this valuable resource, as well as political immigration policies aimed at forest clearing and settlement of public lands, a network of railroads was constructed in the late 19th century (Figure 14) (Armson 2001).

Where pine was being harvested, settlement and commerce usually followed, with settlers providing supplies and amenities to the loggers, farming the lands cleared of timber, and establishing small towns across the region (ODLF 1964b). By the 1890s, many smaller sawmills were producing lumber to support local demand from newly arriving settlers and the building of the railroad (ODLF 1964b,c). During this period, the timber industry embraced a "cut and leave" policy, opening new mills along the railway to exploit nearby forests, only to close the mills when the timber resources were depleted or when economic conditions became unfavourable (see Section 6.1) (Crossen 1976). The prevailing cutting practices were to harvest all the white pine trees except those deemed too difficult or expensive to extract. The industry and mills were the heart of a village's economy and its prosperity was closely tied to the level of logging activity (Crossen 1976).[15] When the timber was gone, the industry moved on to cut the pine "over the next hill", leaving behind small towns that had suddenly lost their primary source of wealth.

By the late 19th century, logging of the Great Lakes Region's extensive, white and red pine forests was at its peak. At this time, U.S. interests controlled almost 4.2 million m^3 of standing timber in Ontario that was being cut and floated to mills in Michigan as sawlogs. In anticipation of Canadian government action to ensure processing of sawlogs inside Canada, in 1897 the U.S. government imposed a tariff on the importation of manufactured lumber products (Armson 2001). The Ontario government retaliated the following year with a "manufacturing condition" that stipulated that all timber cut on Crown land be manufactured in Canada. This effectively reduced the export of white and red pine sawlogs to the small volumes available from private and First Nations lands (Aird 1985, Epp 2000), and greatly stimulated Ontario's lumber industry. This also fostered American investments in Ontario's northern communities through the construction of many large sawmills in pine forests further inland and north that could process 175 to 700 m^3 per day of timber (Figure 15) (ODLF 1965, Armson 2001).

[15] Superior-Martel Forest FMP (2006)

Figure 13. Railroads offered new resource exploitation possibilities in Northern Ontario. (Photo from Archives of Ontario)

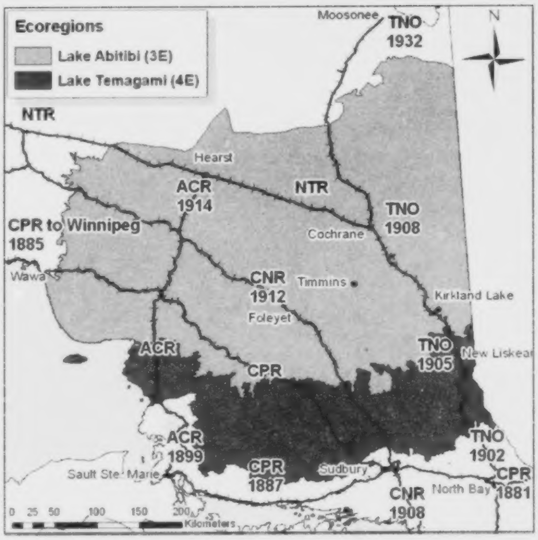

Figure 14. Historical development of railways in northeastern Ontario associated with the forest industry (years from ODLF 1964a,b,c; 1965; 1967). Abbreviations: CNR, Canadian National Railway; CPR, Canadian Pacific Railway; ACR, Algoma Central Railway; TNO, Temiskaming and Northern Ontario Railway; NTR, National Transcontinental Railway.

Coincident with these events, a number of white and red pine sawmills relocated from the Ottawa Valley to North Bay and as far north as Chapleau to access supplies of pine made available by newly granted timber concessions (McKenney et al. 2001). As many as 150 sawmills, many of which were processing pine harvested and transported from northeastern Ontario, were operating on the north shore of Lake Huron in the 1900s.[17] Some 12 sawmills existed near the mouth of the Spanish River in 1915 (ODLF 1965), with smaller mills operating in Biscotasing (1905-1927), Gogama (1917), and Westree (1924-1968) (Crossen 1976).[18] The most important of these new timber concessions was the Montreal River Concession in the Timiskaming management unit, licensed in 1907 to J.R. Booth, Canada's most famous lumber baron (ODLF 1964c, Trinnell 1998).

Figure 15. The William Milne and Sons lumber mill in Temagami, ON (circa 1940). (Photo from Archives of Ontario). This mill was established in 1937 primarily to process white and red pine acquired from the company's own forest operations or by buying more select wood from other companies. The mill closed in 1990 due to financial problems and lack of large diameter white and red pine.[16]

[16] Temagami Forest FMP (2004)
[17] Northshore Forest FMP (2005)
[18] Timiskaming Forest FMP (2006)

White and red pine sawlog production in northeastern Ontario peaked between 1900 and 1910 and declined thereafter, a few decades after peak production in the province as a whole (ODLF 1965, 1967) (Figure 16). Several factors contributed to the overall decrease in the amount of pine harvested, including depletion of the resource by selective harvesting, catastrophic fire that commonly occurred in cutover and newly settled areas, as well as labour shortages caused by a smallpox epidemic in 1901, World War I in 1914-1918, and the Great Depression in 1930-1935 (ODLF 1967). After the depression, the Ontario government made more land available for logging and World War II triggered further expansion and modernization of the white pine forest industry (ODLF 1967). For example, peak activity in large pine and veneer operations occurred around 1947 in Temagami.[19] However, recovery of pine lumbering was short-lived because the limited availability of remaining timber could no longer sustain this industry. Instead, forest industry focused on more abundant species and the yellow birch, maple veneer, and other hardwood industries began (ODLF 1965).

By the middle of the 20th century, the quality and quantity of the pine resource paled in comparison to that of the previous century, with relatively few mills relying solely on processing of pine lumber (see Appendix 2). At the northern edge of the geographical distribution of white pine in northeastern Ontario, the Sheppard and Morse Company acquired the rights to harvest white and red pine in 1948. The mill remained in operation from 1950 to 1965, when it burned. It was eventually rebuilt, and then purchased by the Pineal Lake Lumber Company in 1977.[20]

Despite minor annual fluctuations, white pine harvest levels have been relatively stable over the last decade in Ecoregion 4E, but have diminished in Ecoregion 3E (Figure 17). Traditionally, 68% of the white pine supply in Ecoregion 3E was from dispersed forest stands in which white pine was a minor component, but the scarcity of white pine in this ecoregion, coupled with recognition of the ecological values of these forests, has resulted in decreased availability of white pine for harvest (OMNR 2004e).

4.2 Current importance of white pine

4.2.1 Economic importance of white pine

White pine has historically been the most valuable softwood lumber species in eastern Canada (Farrar 1995), commanding higher and more stable prices than other softwoods (Figure 18). On average, the price for white and red pine sawn lumber has been about 40% higher than that for other veneer quality softwoods. White and red pine represented only 1.9% of the total volume of roundwood manufactured[22] by facilities in MNR's administrative Northeast Region but increased from 1999 to 2005 (Table 2, Figure 19). Most of the white and red pine in the region is now processed in larger mills around Sault Ste. Marie, Sudbury, and North

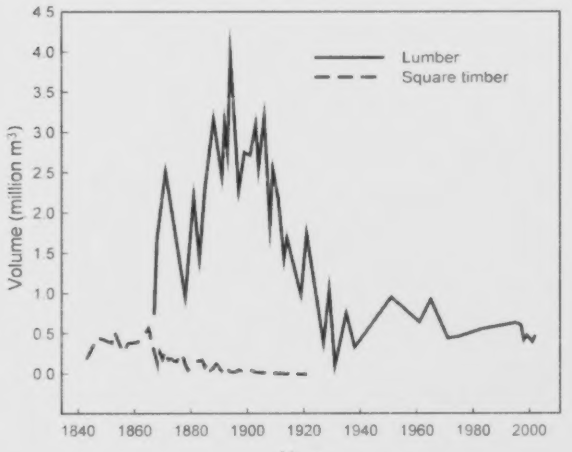

Figure 16. Historical harvest of white and red pine from Ontario's Crown forests. Square timber includes square, waney, boom and dimensional lumber (Adapted from Aird 1985)

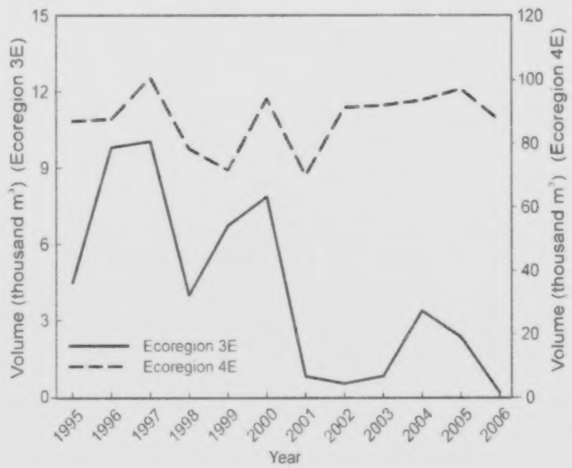

Figure 17. Annual harvest levels of white pine wood volume in ecoregions 3E and 4E from 1995 to 2006.[21]

[19] Temagami Forest FMP (2004)
[20] Superior-Martel Forest FMP (2006)
[21] Data from MNR's scaling database: TREES
[22] Sections of trees with or without bark (logs, bolts, pulpwood, posts, pilings, and other "round" materials)

Table 2. *Proportion of the roundwood manufactured by facilities in the MNR's Northeast Region from 1999 to 2005 by species group.*[23]

Species group	Percentage of the total roundwood volume manufactured
Spruces – Jack pine – Fir	61.9
Poplars – White birch	21.6
White and red pine	1.9
Maple	1.5

Bay (Figure 20) that obtain most of their pine supply from FMUs in or south of Ecoregion 4E. However, some FMUs within Ecoregion 3E still provide most of the white pine supply for local mills (e.g., Cheminis Lumber (Kearns, ON), Devon Limited (Chapleau, ON)).

The wood properties of white pine also provide important diversification opportunities to local and regional economies through value-added forest products (OMNR 1998a). White pine wood is prized for furniture making and cabinet work because of its light weight, strength, creamy-white to yellow colour, and the ease with which it can be worked (Farrar 1995). Its resistance to warp and uniform texture (grain) make it ideal for the manufacture of patterns, doors, moulding, window sashes, trim, siding, panelling, and plywood (Farrar 1995).

4.2.2 Social and cultural importance of white pine

White pine forests provide a desirable environment for a variety of recreational uses. Many tourists and outdoor enthusiasts prefer forests containing white pine, particularly those with old large trees (Figure 21), for their wild undisturbed appearance (Heider 1994). These older forests are rare in eastern Canada, and provide a unique outdoor experience for those seeking peace and solitude (Barnes 1989, Heider 1994). The beauty of the white pine tree itself has been the subject of the works of many writers, artists, and poets, including the Group of Seven who helped shape Canadian art in the 1920s (OMNR 1998a). The history and folklore associated with the lumberjacks of the white pine timbering era of the 1800s have been celebrated in story and song (MacKay 1978).

Old growth forests have received considerable attention in the last few decades due to their rarity and unique ecological, scientific, and natural heritage values (Whitney 1987, Barnes 1989, Clark and Perera 1995, Frelich and Reich 2003). These forests have been defined in scientific and political terms but may be generally characterized as multi-aged stands with large, old living and dead standing trees, large amounts of downed wood, and a complex vertical and horizontal

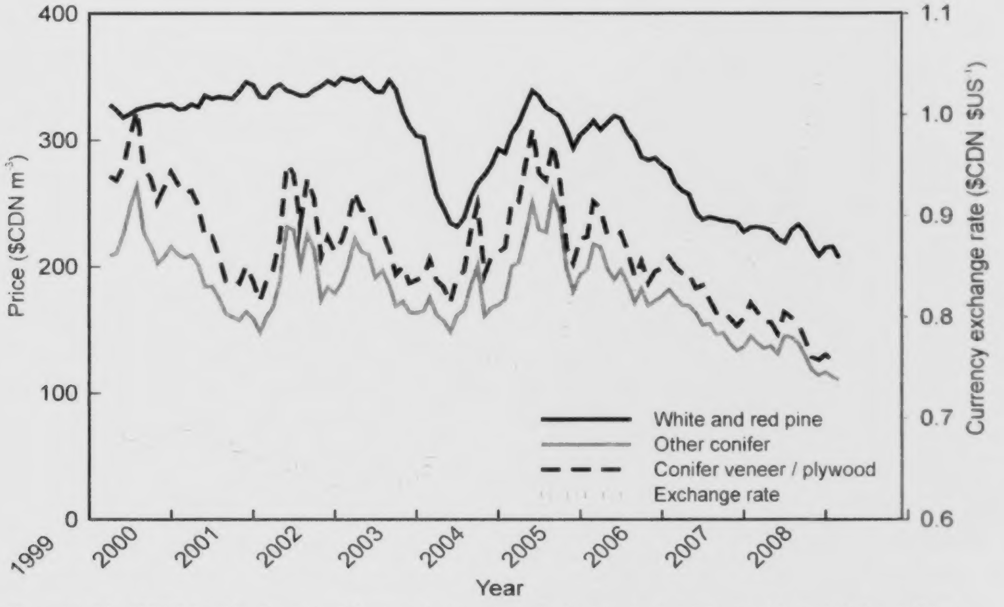

Figure 18. *Price ($CDN) for white pine and red pine sawn lumber as compared to sawn lumber and veneer/plywood of other conifer species processed in Ontario for the period 1999 to 2008.*[24] *Sawn lumber refers to 1" x 6" lumber of standard grade. Exchange rate during this period is presented to show that the recent drop in lumber prices is partly due to the increase in the value of the Canadian dollar.*

[23] Amounts are reference prices used for establishing the Ontario crown timber charges. Values are not in constant dollars.

[24] Data from eFAR, MNR's electronic facility annual return database (http://forest.lrc.gov.on.ca/efar/) (accessed in 2007)

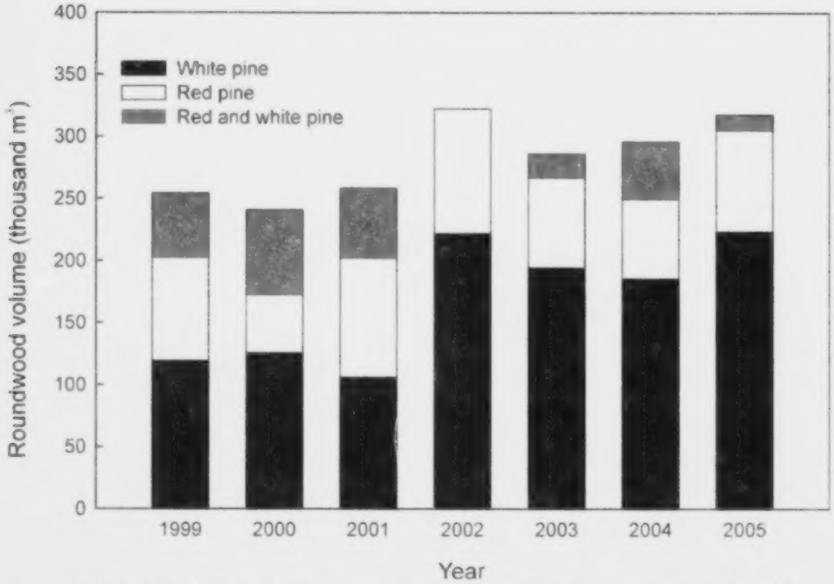

Figure 19. *Volume of white pine and red pine roundwood manufactured in MNR's Northeast Region from 1999 to 2005.*[25] *Manufacturers may report on white pine and red pine separately or combine both species. Most of the combined red and white pine category is likely white pine.*

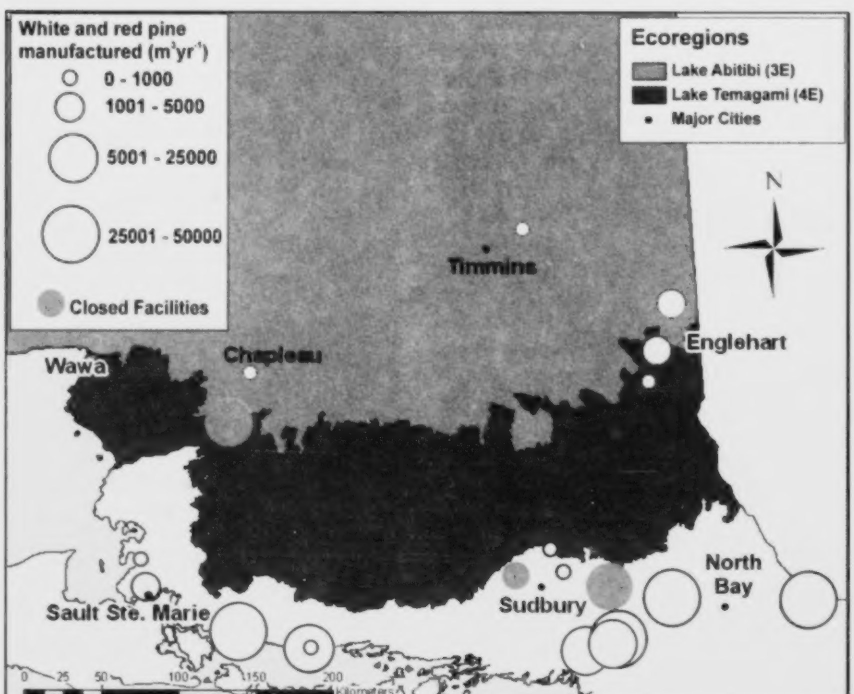

Figure 20. *Location of mills processing white pine and red pine in the MNR's Northeast Region for the period 1999 to 2005.*[26]

[25] Data from eFAR, MNR's electronic facility annual return database (http://forest.lrc.gov.on.ca/efar/) (accessed in 2007)

[26] Data from eFAR, MNR's electronic facility annual return database (http://forest.lrc.gov.on.ca/efar/). Appendix 3, excluding the red pine class (see Figure 19)

structure (Barnes 1989, Carleton 2003, Frelich and Reich 2003). This structural heterogeneity creates a variety of microhabitats for plants and animals, contributing to their relatively high biodiversity (Carleton 2003).

Old growth forests occupied a relatively small proportion of the total area of white and red pine forests at the time of settlement but have become increasingly scarce due to almost two centuries of harvesting and land clearing (Frelich 1995). The unique structure of old-growth white and red pine forests may be preferred habitat by some plant and animal species, but few species have been found to be confined to old growth forests (Whitney 1987, Clark and Perera 1995, Thompson et al. 1995, Jung et al. 1999). These forests also possess ecosystem functions and processes (e.g., primary production, nutrient cycling, succession, wildlife habitat) that are different from the earlier developmental stages of white and red pine forests (Carleton and Gordon 1992, Clark and Perera 1995, Uhlig et al. 2001, OMNR 2003a).

Loss of old growth white and red pine forests may occur through successional replacement by other species following fire suppression, stand-replacing disturbance, and harvesting (see Section 9.2). Maintaining the area of these forests will require both preservation and active management (Barnes 1989, Johnson et al. 1995, Burton et al. 1999). In Ontario, old growth white and red pine forests are given special consideration for conservation and protection due to their social value and contribution to terrestrial diversity (OMNR 2003a). Some of these stands are being protected in parks and conservation reserves (see Section 7.2). Although old growth stands on Crown land are available for harvest, they must be managed such that they are maintained on the landscape (see sections 7.1.1 and 7.3.1).

Figure 21. *Forest stands with large white pine trees are often prized by tourists and recreationists for their aesthetic appeal. (Photo by S. Vasiliauskas)*

5 State of the white pine forest resource

5.1 Historical status and trends

The exact area and volume of white pine present in eastern North America at the time of European settlement is unknown, but its abundance was very likely exaggerated by early settlers in their romantic accounts of the primieval forest. Early land surveys in the United States indicate that high concentrations of white pine forests covered large areas in regions with light, sandy soils (Abrams 2001). Natural disturbance by fire also created mosaics of pine forests of various age classes on the landscape. Fire frequency models suggest that only a small proportion (~ one-third) of these forests likely contained large, old trees (Figure 22). Early provincial records of Crown timber agents also suggest that old growth white and red pine forests with numerous large trees were the exception rather than the rule (Armson and McLeod 2007).

Serious thought was not given to quantifying the extent of pre-settlement pine forests until the early 20th century.

Figure 22. *An example of the structure of a pre-settlement white pine forest in Algonquin Provincial Park. Note that this photo is not representative of most white pine stands during this period, rather it is unique and characteristic of the best stands. (Photo from Algonquin Provincial Park)*

Estimates based on expert opinion and incomplete data offer conflicting values for original area and volume of white pine forests. For example, pre-settlement white pine volume in Canada was estimated at both 36 million m^3 (Betts 1954) and 1.1 billion m^3 (Anonymous 1923). Maxwell (1915) cites a more "conservative" estimate of 1.1 billion m^3 spread over 91 million ha of original pine forests present in the United States and Canada combined. By the 1920s, 59 million m^3 of white and red pine were thought to remain in Canada, much of which likely occurred in Ontario (Anonymous 1923, Sharpe and Brodie 1931).

Most comparisons of pre-settlement with current forest composition in the eastern United States indicate a decline in the abundance of white pine (Abrams 2001). Probably only 25% and <1% of pre-settlement white pine forest and old growth white pine forest, respectively, remain in the U.S. Great Lakes region (Frelich 1995). Similar estimates for Canada are not available. Certainly, all early qualitative predictions of a resource that was "inexhaustible", "interminable", or "sufficient to supply the wants of the citizens…for all time to come" were proven false by the end of the 1800s.

The best current estimates of the abundance and distribution of Ontario's pre-settlement white pine forests are derived from information collected by Crown land surveyors (Jackson et al. 2000, Leadbitter et al. 2002, Pinto et al. 2008). In the late 18th and early 19th century, land surveyors walked township boundaries and listed the tree species present by ranked abundance. These records provide a glimpse of forest cover composition that resulted from the pre-settlement natural disturbance regime. Land surveys conducted from 1857 to 1922 offer a relatively unbiased sample of pre-settlement forest conditions in ecoregions 3E and 4E (Pinto et al. 2008). This historical information was used to estimate the initial species composition of the townships surveyed and then compared with current FRI data to assess the relative change that has resulted from past forest exploitation and more recent forest management (Pinto et al. 2008). From these comparisons, forests dominated by white and red pine in ecoregions 3E and 4E were estimated to have decreased in abundance by about 84 and 59%, respectively (Table 3).

The historical decrease in the forested area dominated by white pine can be attributed to several factors (Abrams 2001, Frelich 2002, Pinto et al. 2008). In

Table 3. *Comparison of pre-settlement and current forest area dominated by white pine and red pine in ecoregions 3E and 4E (Adapted from Pinto et al. 2008).[27] Both the proportion of the total area surveyed and the estimated area (ha) (in parentheses) are presented.*

Dominant species	Proportion of forest area (%)			
	Ecoregion 3E		Ecoregion 4E	
	Pre-settlement	Current	Pre-settlement	Current
Red and white pine	0.16	no data	4.85	no data
	(22,800)	---	(194,000)	---
Red pine	0.14	0.02	3.41	1.22
	(19,320)	(2,760)	(136,400)	(48,800)
White pine	0.36	0.10	9.3	5.95
	(49,680)	(13,800)	(372,000)	(238,000)
Total	0.67	0.11	17.57	7.17
	(92,460)	(15,150)	(702,800)	(286,000)

some stands, harvesting of all available white pine trees effectively removed the residual seed source, preventing regeneration. In high-graded stands, only genetically inferior trees or those with dead tops or high levels of rot remained as seed sources for regeneration. Repeated catastrophic fires were common after harvesting (Alexander 1980). These fires further diminished the area of white pine forests by killing any residual overstory seed trees, as well as any advance regeneration that may have been present (Epp 2000, Frelich 2002). Historical harvesting practices coupled with wildfire reduced the regeneration capacity of white pine and favoured stand conversion to other forest types (ODLF 1967, Armson 2001, Pinto et al. 2008). Many of today's white birch and low quality hardwood forests likely once supported white pine (Day and Carter 1991).

5.2 Current status and trends

Current information on the distribution, abundance, species composition, and age structure of forests containing white pine are derived from Ontario's FRI. The FRI is created from aerial photographs and supplemental ground surveys that are used as a basis to classify stands by species composition[28] and structure. This information is later used by SFLs to classify productive stands into a series of distinct forest units that are most often[29] defined based on regional standard forest units (SFU) (Watt et al. 2003) (Table 4). Those SFUs are later combined into provincial forest types that are used for various provincial reporting programs.

Table 4. *Stand compositional criteria used to define standard forest units dominated by white and/or red pine (Watt et al. 2003).*

Standard forest unit	Stand composition criteria
PR1	70% or more red pine
PW1	30% or more white pine **or** 40% or more of a combination of white pine and red pine, white spruce, and hemlock
PRW	40% or more white pine and red pine

5.2.1 Distribution, abundance, and composition

Although forests containing white pine do not occupy as large an area now as they did prior to European settlement (Jackson et al. 2000, Leadbitter et al. 2002, Pinto et al. 2008), they still occupy a broad geographic range (OMNR 2007b). Very little of Ecoregion 3E contains white pine and what does exist occurs as scattered individuals or is clumped in stands dominated by other tree species (Figure 23, Table 5). Overall, the percentage of white pine in the forests of Ecoregion 3E is relatively small, with it forming less than 30% of the stand in 90% of the forests containing white pine (Figure 24). White pine is much more abundant and widespread in Ecoregion 4E, where it may form up to 60% of a stand (Figure 23, Table 5). Nonetheless, about 86% of the white pine forests of Ecoregion 4E contain less than 30% white pine. For both ecoregions, white pine abundance has changed little between 2001 and 2006 (Figure 24).

[27] Forest composition indicated in Table 3 differs slightly from that given in Section 5.2 of this document because values from Pinto et al. (2008) were estimated from township boundaries to match sampling methods used by surveyors. Approximate areas occupied by these species are presented in parentheses below actual percentage values, and were calculated using total area of 3E (13.8 million ha) and 4E (4 million ha). These area values are presented only to provide the reader with a spatial perspective on the historical change that has occurred, not as robust quantitative estimates.

[28] Species composition in this context is defined by the proportion of the crown occupied by different tree species as assessed by photo interpretation.

[29] Standard forest units for northeastern Ontario boreal forests (Watt et al. 2003) are suggestions only and individual SFLs are encouraged to develop their own forest units.

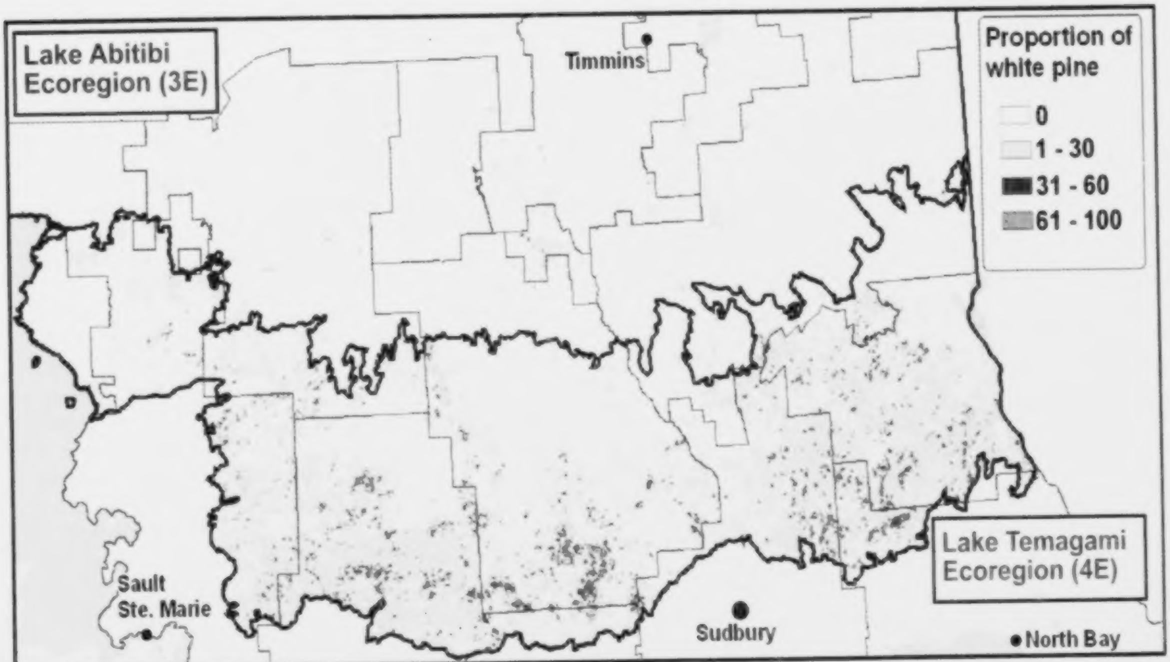

Figure 23. *Spatial variation in proportion of white pine (by crown occupancy) in the forests of ecoregions 3E and 4E in 2006. Major towns and the boundaries of forest management units are provided for reference. Area includes forest management units, provincial parks, and conservation reserves on Crown land.*

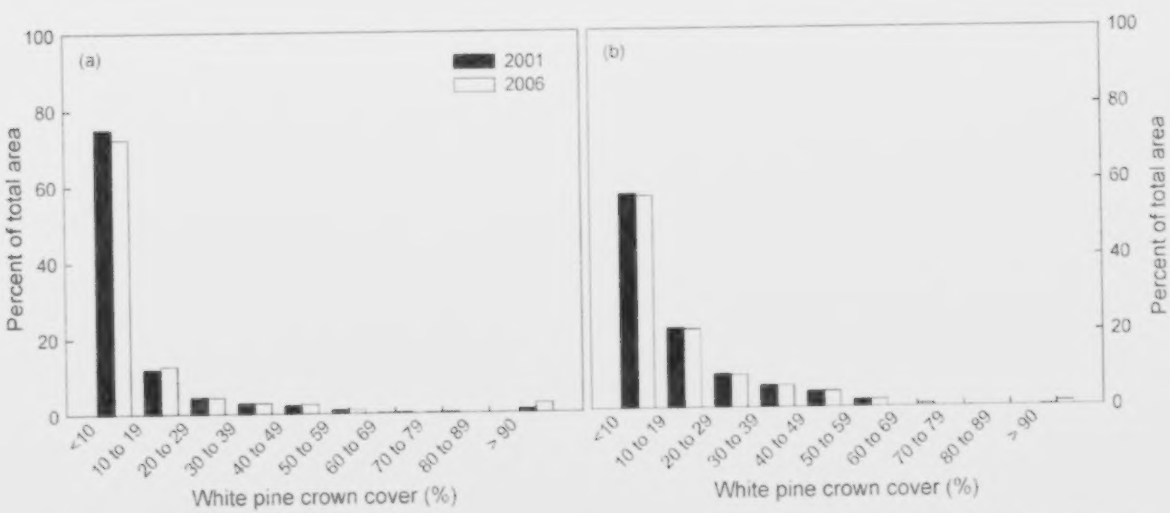

Figure 24. *Comparative percent area of forests containing different proportions of white pine crown cover within ecoregions (a) 3E and (b) 4E in 2001 and 2006. Area includes forest management units, provincial parks, and conservation reserves on Crown land.*

Data for productive forest on Crown land derived from the FRI compiled for the *State of the Forest Report 2006* (OMNR 2007b).

Table 5. *Area of forests containing white pine and dominated by white pine and red pine in ecoregions 3E and 4E.*[31]

Category	Ecoregion			
	3E		4E	
	Area (ha)	Area (percent of total)	Area (ha)	Area (percent of total)
Forest containing white pine	60,170	0.58	1,009,512	30.99
Forest dominated by white pine and red pine	5,754	0.06	276,532	8.49

Table 6. *Proportion of the total white pine volume of ecoregions 3E and 4E in each provincial forest type.*[32]

Provincial forest type	Ecoregion	
	3E	4E
PRW (white pine and red pine)	31.8	57.5
MIX (mixedwood)	36.0	10.9
MCU (mixed conifer upland)	15.9	18.8
BWT (white birch)	9.7	7.1
POP (poplar)	3.3	1.0
TOL (tolerant hardwoods)	1.8	3.8
PJK (jack pine)	1.0	0.4
MCL (mixed conifer lowland)	0.6	0.4

Table 7. *Average species composition for stands of the white pine and red pine (PRW) forest type in ecoregions 3E and 4E.*[33]

Ecoregion 3E		Ecoregion 4E	
Species	%	Species	%
White pine	47.8	White pine	35.5
White birch	17.1	White birch	15.4
White spruce	8.9	Red pine	13.0
Populus sp.	6.9	Black spruce	6.6
Balsam fir	4.9	*Populus* sp.	6.6
Red pine	3.8	White spruce	5.8
Black spruce	3.4	Balsam fir	5.4
Eastern white cedar	3.2	Jack pine	3.9
Jack pine	2.5	Eastern white cedar	2.8
Sugar maple	0.1	Red maple	2.8
		Sugar maple	0.7

White pine is a component of 0.58% of the forest area in Ecoregion 3E, with 0.06% of the forest area in the PRW forest type (Table 5). About 31% of forest area in Ecoregion 4E contains white pine, with about 8.5% in the PRW forest type (Table 5). In ecoregions 3E and 4E, white pine is a component of 8 provincial forest types (Table 6). Where white pine is a smaller component of forests, it occurs mainly in mixedwood (MIX), mixed conifer upland (MCU), and white birch (BWT) provincial forest types, contributing as much as 36% of stand volume (Table 6). In Ecoregion 3E, white pine is primarily associated with boreal forest species and more than two thirds of total white pine volume occurs in forest types other than PRW (Table 6). In Ecoregion 4E white pine occurs primarily with red pine but the PRW forest type here is associated with a number of tolerant hardwood species more common further south (Table 7).

5.2.2 Age structure

The forest age class distribution resulting from natural disturbance prior to settlement is unknown. However, information from fire history studies has been used to develop fire frequency models that use exponential decay or Weibull functions to estimate, for example, the fire interval frequency distribution for a given area (Johnson and Gunsell 1994). For a fire-dependent forest type, this can also be viewed as the hypothetical natural, pre-settlement age-class distribution, with relatively large areas of younger stands and progressively declining amounts of older forests (Figure 25). Using the negative exponential model, a forest landscape in equilibrium has 37% of its area in stands older than the fire interval (Van Wagner 1978, Johnson and Van Wagner 1985). This pattern is quite different from the square (or rectangular) hypothetical age class distribution of a forested landscape managed under an even-aged industrial rotation for timber production (Figure 25). This age class distribution, with equal amounts of younger and older stands, is reflective of a balance between area harvested and successful regeneration to the original forest type.

[31] Data from the most recent FRI compiled for the State of the Forest Report 2006 (OMNR 2007b).

[32] Data obtained by applying Plonski's normal yield tables (Plonski 1981) to species composition and stocking data from the FRI compiled for the State of the Forest Report 2006 (OMNR 2007b).

[33] Data from the most recent FRI compiled for the State of the Forest Report 2006 (OMNR 2007b).

[34] The PRW provincial forest type generally consists of a combination of the PR1, PW1 and PRW standard forest units, although Licensees may use slightly different forest units (see Table 4).

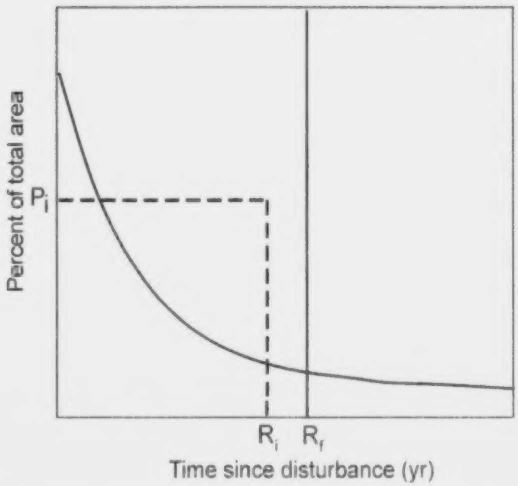

Figure 25. *Hypothetical equilibrium landscape age class distribution of unmanaged, natural forest disturbed by stand-replacing fire (curved line) at mean fire interval R_f (solid, vertical line) compared with that for even-aged forests clearcut harvested at a fixed industrial rotation (R_i) (dashed, vertical line).*

In reality, the age class distribution of a given forest type is quite different from these two hypothetical relationships (Burton et al. 1999). The current age class structure of the PRW[34] forest type in ecoregions 3E and 4E is one of increasing area of younger stands, maximum area of stands 100 to 160 years old, and increasingly smaller amounts of older forests (Figure 26).[35] The relative lack of stands of the PRW forest type that are younger than 80 years likely results from a combination of fire suppression since the 1930s and insufficient silvicultural effort given to regeneration (Hosie 1953, Day and Carter 1991, Carleton and MacLellan 1994, Weyenberg et al. 2004). The higher proportion of stands less than 20 years old compared with stands 21 to 40 years old suggests that regeneration efforts in Ecoregion 3E over the last two decades have been successful.[36] The relatively small area of older stands of the PRW forest type is reflective of the natural landscape pattern in forest ecosystems affected by wildfires (Johnson and Gunsell 1994).

This imbalance in the age structure of the PRW forest type in both ecoregions has negative implications for future wood supply as well as for the long-term maintenance of old growth white pine on the landscape (see Section 9). White pine forests are classified as "old growth" in Ecoregion 3E when they contain white pine trees that are between 130 and 230 to 300 years old and in Ecorgegion 4E when they are between 150 and 210 to 310 years old (Uhlig et al. 2001). Currently, 1,319 and 31,826 ha of old-growth white and red pine occurs in ecoregions 3E and 4E, respectively. Maintaining old growth white pine on the landscape is a critical component of the forest management planning process (see Section 7.3.1).

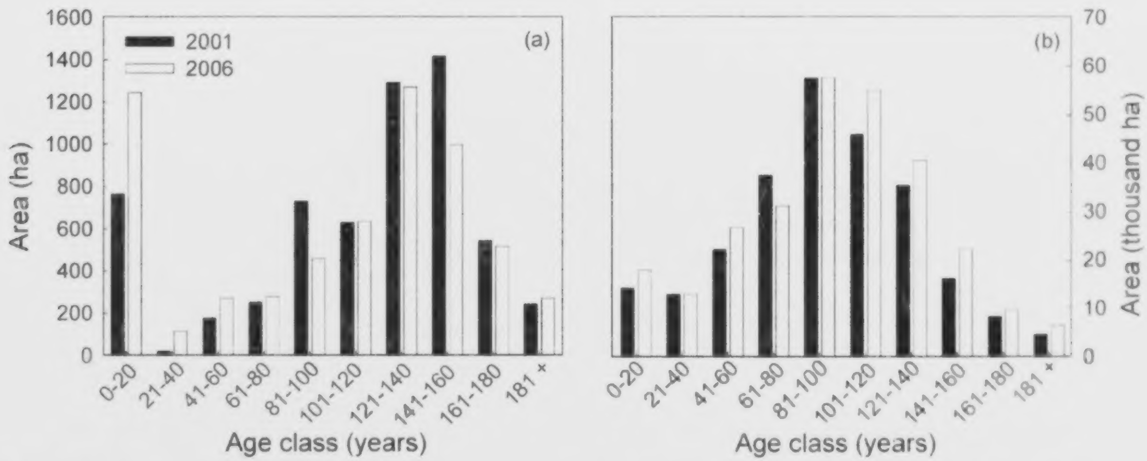

Figure 26. *Age class structure of white pine and red pine forests in ecoregions 3E (a) and 4E (b) in 2001 and 2006. (Data from 2001 and 2006 provincial forest resource inventory. Note difference in scale between graphs.)*

[35] A similar age class structure for white pine dominated forests in MNR's Northeast Region was reported previously (Osborn 1985).

[36] It is not possible to determine how much of this increase is due to establishment of red pine plantations. The apparent increase between 2001 and 2006 could also be partly a result of differences in inventory procedures used in 2001 and 2006 FRIs (i.e., a lower minimum size for delineating white pine stands was used in 2006).

6 Historical evolution of white pine management[37]

6.1 Colonial growth and forest resource exploitation (1800-1949)

For almost 150 years (1800-1949), white pine was harvested with the sole objectives of short-term economic gain and land clearing to encourage settlement and support economic development of the province (see sections 4.1.2 and 4.1.3) (Aird 1985, 2001; Armson 2001). These objectives resulted in widespread conversion of white pine forests to other forest types, and very early raised concerns about the economic viability of a forest policy of resource exploitation. This realization coincided with the birth of the forest conservation movement in North America in the late 19th century as the ecological values of forests were first recognized and the public appetite for forest recreation grew. At this time, urbanites from southern Ontario began to visit forested areas to the north for canoeing, hunting, fishing, and the therapeutic value of the wilderness. The need to balance the objectives of forest industry and the public for the rapidly decreasing forest resource culminated in legislation and political action to separately establish parks for recreation and forest reserves for lumbering (Epp 2000). One such piece of legislation, the *Forest Reserves Act* of 1898, sought to reserve the timber in selected areas for the lumber industry (i.e., logging would be allowed but land clearing by settlers would be prohibited), avoid conflict with settlement, and hopefully, ensure a perpetual supply of pine timber (Epp 2000). This act created the Temagami Forest Reserve in 1901 and Mississagi Forest Reserve in 1904 (Lambert and Pross 1967). At the time, the Temagami Forest Reserve was considered one of the best remaining tracts of virgin white and red pine forest in Ontario (Epp 2000). However, the area's scenic beauty was quickly recognized by the public, the tourist industry blossomed, and construction of roads and railroads increased public access and recreational use of this area (Epp 2000).

The early 20th century brought political acknowledgement of forestry as a profession and the significant potential contributions of scientific forestry to forest management. The appointment of Ontario's first provincial forester in 1904, establishment of Canada's first Faculty of Forestry at the University of Toronto in 1907, and several international conferences devoted to forest management (e.g., Canadian Forestry Convention, Ottawa, 1906) were testament to this new public and political appreciation of forestry (Epp 2000). Assessment of forest resources and regeneration on cutover lands and within forest reserves were among the first scientific activities performed, but contained few positive findings with regard to the legacy of logging pine forests of the province (Sharp and Brodie 1931, Mayall 1941, Hosie 1953). These efforts concluded that harvested white pine forests often did not regenerate back to white pine, and both the prevailing logging practices and repeated fires contributed to this failure (Mayall 1941, Hosie 1953, Aird 1985). Although the need for regeneration after logging and/or fire was recognized, the primary government concern was fire protection of forests and the valuable timber they contained (Zavitz 1960, Armson 2001). The first major reforestation efforts in Ontario were instead focused on restoring forest cover to lands in the southern region of the province that had been degraded by a sequence of clearing, farming, and abandonment to erosion (Zavitz 1960, Borczon 1986).

Publicly funded forest research began early in the 20th century and contributed greatly to the knowledge base needed to improve management of white pine. Research and operational experience with white pine plantations and the damage caused by blister rust and weevil, coupled with an increased understanding of white pine ecology and silvics, led to the establishment of research trials at the Petawawa Research Forest. These trials included silvicultural approaches to regenerate white pine beneath overstory forest canopies using partial cutting systems (Stiell 1994, Burgess and Wetzel 2002, Bevilacqua et al. 2005) and thinning trials designed to establish and/or release white pine regeneration (Horton and Bedell 1960, Stiell 1994). The findings and recommendations from these and related studies were applied operationally and have slowly evolved to the uniform shelterwood silvicultural system most commonly used to regenerate white pine-dominated stands in Ontario (see Section 7.1.3)(OMNR 1998a).

6.2 Sustained yield and multiple use (1950-1979)

Throughout the first half of the 20th century, the primary forest management objective was timber production, with large, healthy, and valuable trees receiving priority for harvest.[38] White pine stands were still

[37] For a more thorough discussion of the evolution of forest management in Ontario, readers are directed to Lambert and Pross (1967), Epp (2000), Euler and Epp (2000), and Armson (2001).

[38] For example, Temagami Forest FMP (1960), Superior Forest FMP (1987-2007)

selectively logged with little attention to securing natural regeneration of any species, resulting in continued widespread conversion of white pine stands to other forest types (Hosie 1953). Poor natural regeneration, due in large part to seed source removal and, in the case of planting, poor competition control, were formally recognized and reported (Mayall 1941, Hosie 1953). When plantations in cutovers were attempted, extensive damage by blister rust and weevil caused them to be viewed as failures (ODLF 1965). Poor plantation performance and lack of effective pesticides to control the weevil led forest managers to adopt a policy of white pine liquidation and conversion to the more easily grown jack pine and red pine, a policy that lasted for many decades (ODLF 1965, McNutt 1985).

In more northern areas, forest managers assumed that white pine could not survive and grow well in the harsh boreal climate, and harvest and species conversion was pursued at a rate determined by the demand of local sawmills.[39] Past FMPs provide examples of the acknowledged practice of "cutting oldest first" that continued until the early 1990s (Pinto et al. 2008). For example, in the current FMP for the Superior-Martel Forest, it was determined that white pine would be harvested at a rate dictated entirely by the short-term needs of Pineal Lake Lumber.[40]

While scientific and operational knowledge of white pine regeneration and management was improving (Horton and Bedell 1960, Wilson and Hough 1966, Sullivan et al. 1985), government management of Crown forest lands began to evolve towards greater, more effective stewardship of the many values of the province's forest resources. The *Forest Management Act* of 1947 introduced the concept of forest management planning, with companies being required to submit long-term management plans with spatial identification and characterization of areas to be harvested in terms of forest types, tree species, stand size, and stand ages before receiving Crown approval to proceed (ODLF 1965, Epp 2000). The *Crown Timber Act* of 1953 standardized forest management activities and the relationship of government with the forest industry (Epp 2000). Recognition that pine forest did not naturally regenerate well after clearcutting or selective cutting led to an increase in planting on clearcut sites. Planting of white pine in MNR's Northeast Region varied during this period, probably as a result of changes in government policies and economic conditions that influenced funding for silviculture (Figure 27). However, the regeneration success of these plantations and others have generally been low, primarily due to inappropriate timing and intensity of competition control and damage by blister rust and weevil (e.g., see Bryson et al. 1996).

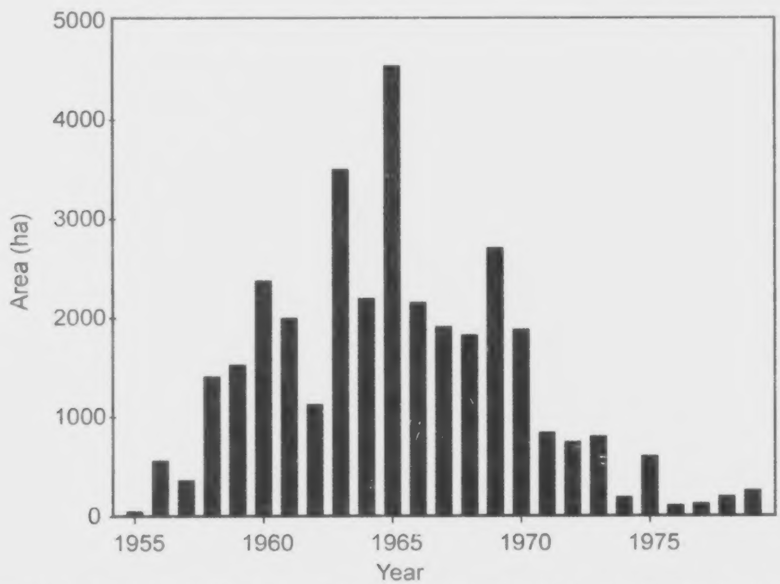

***Figure 27**. Area planted to white pine in clearcuts from 1955 to 1986 in the MNR's former Northeast Region. (Adapted from Woods and Miller 1995)*

[39] Superior-Martel Forest FMP (2006)

[40] Superior-Martel Forest FMP (2006). The mill closed in 2005, in part due to lack of white pine supply.

In 1954, government forest policy began to formally move towards multiple use, sustained yield forestry with the release of *Suggestions for a Program of Renewable Resources Development*, a white paper that proposed integrated management of forests for timber as well as other values (e.g., wildlife, water, recreation) (Lambert and Pross 1967, Epp 2000). This report also documented serious concerns about future wood supply and, importantly, addressed predictions that if current rates of harvest were allowed to continue, the entire inventory of white pine forests present at the time would be harvested in less than 20 years. This wood supply shortage would require a temporary reduction in harvest of white pine coupled with greater utilization of other tree species by existing pine sawmills, with the intent of allowing time for the younger, smaller pine stands to grow to sawlog size. The white paper also called for renewed efforts to secure adequate pine regeneration to meet future demand of pine sawmills. This led to additional efforts aimed at increasing silvicultural activities and the success of forest regeneration programs, such as *Project Regeneration* initiated in 1958. Despite these efforts, concerns over wood supply and regeneration, and the roles and responsibilities of industry and government in addressing these issues, continued to plague the MNR through the 1970s.

The 1950s were also characterized by explosive growth in public demand for lands for outdoor recreation and resulted in passage of the *Provincial Parks Act* in 1954. Prior to 1950, few provincial parks had been established but increased interest in various recreational pursuits resulted in more than 100 parks being created by 1970. Attempts to manage parks using the principles of multiple-use inevitably led to conflicts between extractive industries and the public as well as the formation of increasingly powerful non-government organizations[41] that sought to prohibit logging, mining, and road construction from these areas (Aird 2001).

In 1975, the Environmental Assessment Act was passed, requiring that the activities, or "undertakings", of the MNR (including forest management and operations plans, road construction, harvesting, and silvicultural activities), be publicly evaluated before their implementation on Crown land was approved. Evaluation of alternatives to these undertakings as well as consideration of their effects on social, economic, cultural, and ecological values was also required.

6.3 Sustained yield and integrated resource management (1980-1993)

The conflicts and difficulties associated with attempts to balance the multiple interests in forest values continued into the 1980s, and led to a strategic land use planning exercise, which had varying levels of success. This exercise was an internal MNR process and was criticized by many for its preoccupation with timber production and lack of public input. Public demand for parks further increased during this period, and conflicts between forest industry and other forest users continued. Release of the *Temagami District Land Use Guidelines* in the early 1980s resulted in a heated, highly publicized dispute over management of natural resources that revolved around harvesting old growth white and red pine forests in an area with significant recreational value. This issue provides an excellent historical example of the evolution of Ontario's forest policy and the need to find an approach to forest management that adequately balanced the multiple interests of those using the province's forests (Hodgins 1992, Epp 2000, OMNR 2003a). An important outcome of this controversy was increased study of pine ecology, the natural role of fire in these ecosystems, the structure and function of old growth white and red pine forests, and concerted research efforts to develop and test ecologically sustainable management practices for the province's white and red pine forests (Hodgins 1992). As well, in 1992 the Old Growth Forests Policy Advisory Committee and the Old Growth Science Committee were appointed by MNR to make recommendations to the minister on issues concerning old growth forest ecosystems (OMNR 2003a).

Although perhaps not recognized at the time, the challenges posed to the MNR by the passing of the *Environmental Assessment Act* in 1975 would eventually result in the abandonment of the concept of sustained yield as a guiding principle for forest management. Between 1977 and 1987, the MNR made five attempts at a class environmental assessment of its forest management activities. It was finally found acceptable and approved in 1994, but included 115 terms and conditions on which the approval was based, and marked the end of the era of sustained yield as the governing forest policy (Ontario Environmental Assessment Board 1994).

[41] e.g., Algonquin Wildlands League, Ontario Federation of Anglers and Hunters

7 Current white pine management: era of ecological sustainability (1994-present)

The shift in paradigm that occurred through the 1980s and 90s was characterized by the slow realization that forest management based on a policy of sustained yield was no longer publicly acceptable and did not adequately address conservation of biodiversity (Apsey et al. 2000, Euler and Epp 2000, Neave et al. 2002). The almost 50-year history (1950-1993) of not achieving a balance between harvest levels and regeneration (sections 6.2 and 6.3), provides a striking example of the implications of using a concept (sustained yield) that is sound in principle but difficult to implement. The province has since moved to forest management policy based on the concept of ecological sustainability (Epp 2000, Euler and Epp 2000). At the heart of this concept is ecosystem management, which seeks to develop management plans that are ecologically sustainable, economically viable, and socially acceptable (Gilmore 1997, Euler and Epp 2000). In 1994, in its *Policy Framework for Sustainable Forests*, the MNR stated that its mission was "to ensure the long-term health of forest ecosystems for the benefit of local and global environments, while enabling present and future generations to meet their material and social needs" (OMNR 1994).

The *Crown Forest Sustainability Act* (CFSA) (R.S.O. 1994, c. 25) and the *Class Environmental Assessment for Timber Management on Crown Lands in Ontario* were aimed at legislating the concepts and approaches of ecological sustainability and ecosystem management of Crown forests to meet the environmental and economic needs of present and future generations. Today, the MNR has in place a comprehensive framework for managing white pine and other forest resources on Crown land (see sections 7.1 and 7.2). Some lands are conserved in provincial parks and conservation reserves, while most are actively managed for timber, wildlife, biodiversity, and other values based on the CFSA. On FMUs, sustainability is ensured through legislated policy and planning requirements. Follow-up monitoring (see Section 7.3.4) and research (see Section 7.3.5) are used to assess the effectiveness of forest management and to provide new information that can be used to continually improve and update forest policy and practice within an adaptive management framework.

The Ontario government has endorsed the principle of emulating natural disturbances as a strategy to maintain biodiversity in managed forests. This is accomplished through the use of forest practices that, within the limits of silviculture requirements, emulate natural disturbances and landscape patterns. The rationale behind this approach is that forest-dwelling species have adapted to natural disturbances such as fire over thousands of years. Thus, existing white pine stands must be managed to create the variety of age classes at the landscape scale that would have resulted from natural disturbances (OMNR 2001a). This approach is intended to maintain suitable habitats for plant and wildlife species that live in white pine forests, including ecological functions (e.g., nutrient and carbon cycling) associated with natural disturbance patterns.

Direction on how to emulate natural fire disturbance events and patterns at both landscape and stand levels is also provided in a forest management guide (OMNR 2001a). At the landscape level, SFL holders are directed to provide a range of sizes of harvested areas that emulates the natural disturbance pattern. At the level of harvest blocks (designed to emulate individual fire events), insular and peninsular residual patches of trees are to be left in areas managed under the clearcut and shelterwood silvicultural systems. To maintain the biological legacy of the initial stand, a minimum number of well dispersed trees are to be retained within harvested areas, some of which must be large diameter, live, existing (or potential) high quality cavity trees (Figure 28).

Funding for silviculture by the government and forest industry has historically been cyclic, with investments generally based on short-term economic considerations rather than sustainable forest management. This disconnect between funding levels and the financial requirements of silviculture programs was to be addressed by the CFSA, which requires a portion of the Crown charges (i.e., stumpage fees) paid by SFL holders for the harvest of timber to be placed in a forest renewal trust fund. These funds are later used by SFL holders to support regular silviculture operations as outlined in their current FMPs. This more stable, secure funding model is intended to introduce more efficiency and flexibility into the operational application of regeneration activities (e.g., mechanical site preparation timed to good seed years to secure natural regeneration).[42]

[42] Nipissing Forest IFA (2001, 2006)

Figure 28. *Large white pine tree retained after a seed tree clearcut in Regan township in the Romeo-Malette forest management unit near Timmins, ON. (Photo by S. McPherson)*

7.1 Forest management units

The CFSA stipulates that publicly owned forests be managed sustainably to conserve biodiversity and productivity. Under this legislation, forest harvesting on a FMU requires a license and an approved FMP. The FMP describes the strategies and activities that the license holder will use to achieve sustainability, and must address the past, present, and future state of forest resources. Forest management plans must uphold the principles of the CFSA and are guided by the forest management planning manual (FMPM) (OMNR 2004c). A series of associated policies, strategies, and guides[43] have been developed to help SFL holders ensure that timber and other commercial forest products, as well as habitat, resource-based tourism, and cultural heritage values are sustained (e.g., Naylor et al. 1996, Watt et al. 1996, OMNR 1998a, 2001b, 2003b). Of greatest importance to management of the white pine forest resource are the *Old Growth Policy for Ontario's Crown Forests* (Section 7.1.1), *Forest Fire Management Strategy* (Section 7.1.2) and provincial silvicultural guides (Section 7.1.3) that are discussed in more detail below.

A series of wildlife habitat guides help to address more specialized habitat requirements of some key wildlife species, including bald eagles and several other birds. For example, known nesting sites of bird species that are sensitive to harvesting are designated additional protection, within and around which harvesting, access, regeneration, and maintenance activities must be modified. Other wildlife habitat guides specify how white pine stands can be managed to provide winter cover for white-tailed deer and moose.

7.1.1 Old growth policy

In 1994, the *Class Environmental Assessment for Timber Management on Crown Lands in Ontario* (Ontario Environmental Assessment Board 1994) required the MNR to establish an old growth policy. The result was the publication of the *Conservation Strategy for Old Growth Red and White Pine Forest Ecosystems* (OMNR 1995), which was later replaced by the *Old Growth Policy for Ontario's Crown Forests* (OMNR 2003a). The policy describes MNR's plan for the conservation of older trees in all types of Crown forest ecosystems and directs that old growth conditions and values will be identified and present on all Crown forest lands now and in the future. This direction is intended to conserve biodiversity at levels that maintain or restore ecological processes, while allowing for sustainable development.

The MNR's plan for the conservation of older trees in all types of Crown forest ecosystems is being implemented in protected areas through the natural heritage planning process under the authority of the *Provincial Parks and Conservation Reserves Act* (R.S.O. 2006, c.12), and in actively managed forests through the forest management planning process under the CFSA. The MNR has also produced a document to help policy developers, forest managers, specialists, and practitioners to meet the requirements of the old growth policy (OMNR 2007a).

7.1.2 Fire management policy

The MNR's *Forest Fire Management Strategy for Ontario* (OMNR 2004a) embraces a balanced approach to fire management that recognizes both the negative (e.g., fibre loss) and positive (e.g., regenerating fire-dependent ecosystems) effects of fire. This fire strategy allows forest managers to identify where different fire response options will be used. Response options include full response, modified response, or monitoring. This means that efforts can be directed at extinguishing the fire (full response), directing the fire to achieve preset objectives (modified response), or monitoring the fires to determine if beneficial ecological

[43] A complete list of current guides can be found at: http://www.mnr.gov.on.ca/en/Business/Forests/2ColumnSubPage/STEL02_164533.html

or hazard reduction effects are achieved. Maintaining fire-dependent ecosystems in provincial parks and conservation reserves may require the re-introduction of fire (Voras 1994, OMNR 2004a, Van Sleeuwen 2006). MNR's fire management strategy allows mangers of protected areas to establish their own fire management objectives (OMNR 2004b). This is of particular importance to management of some old growth white and red pine stands that likely cannot be preserved without intervention (Barnes 1989, Voras 1994, McRae et al. 1994, Burton et al. 1999).

Prescribed burning can be used to improve white and red pine regeneration in managed forests (Van Wagner and Methven 1978, Olson and Weyrick 1987, McRae et al. 1994), as well as to meet conservation objectives for protected white pine forests (McRae et al. 1994, Tester et al. 1997, Beverly and Martell 2004) (see Section 7.1.3 - *Site preparation*). In the latter case, timely reintroduction of low intensity fire through prescribed burning (or allowing some natural fires to burn) can be used to perpetuate these ecosystems by minimizing their natural succession to more shade-tolerant species. Forest managers who wish to use prescribed burns on Crown land must follow MNR's prescribed burning operations policy (OMNR 2008). An expert system for understory prescribed burns is available from MNR's Aviation and Forest Fire Management Branch to assist forest managers with the assessment of potential candidate sites for prescribed fire (OMNR 1998b).

7.1.3 Silvicultural guides

The MNR's silviculture guides (e.g., OMNR 1998a, OMNR 2003b) describe a range of acceptable management practices and silviculture options that SFL holders can apply to individual stands to achieve a desired future forest condition. The suite of options selected will depend on forest type, stand structure and composition, site factors, vegetation type, management objectives, and other factors.

Silviculture systems

The three primary silvicultural systems identified in the province's silviculture guides that can be legally used in Ontario are the clearcut, shelterwood, and selection systems. These systems represent a continuum of decreasing harvest intensities that to some extent emulate the residual canopy structure created by the varying intensities and forms of some natural disturbance agents. In Ontario and in the U.S. Great Lakes region, natural disturbance by wildfire created suitable conditions for the establishment and growth of white pine (see Section 3.3) (Day and Carter 1990, Kershaw 1993a, OMNR 1998a, Frelich 2002). Because of the disturbance regime to which it has adapted and its intermediate shade tolerance, white pine is generally managed using either of the even-aged silvicultural systems, i.e., clearcut or shelterwood. The choice of silvicultural system depends on the amount of white pine present, the management objectives for the stand, as well as other considerations such as risk of disease.

In mixedwood forests of ecoregions 3E and 4E, where the white pine component of the stand is insufficient to ensure its natural regeneration, some form of clearcutting is commonly prescribed. Forests with less than 4 m^2 ha^{-1} basal area (roughly 14 trees ha^{-1}) with an average dbh (breast height diameter) of 30 cm) of white pine are typically managed using a *clearcut with standards* system, a variation of the clearcut system that retains some live white pines (often older, larger trees) to meet ecological and silvicultural objectives. Stands with between 4 and 12 m^2 ha^{-1} basal area (roughly 42 trees ha^{-1} averaging 30 cm dbh) are usually managed with the *clearcut with seed tree* system, a modification of the clearcut silviculture system that retains 10 to 35 well spaced, good quality white pine trees per hectare to provide a residual source of seed for natural regeneration (Figure 29) (OMNR 1998a). Regeneration of white pine in stands harvested using the clearcut system requires some combination of both natural and artificial regeneration and increased attention to control of competition and weevil damage (Horton and Bedell 1960, Stathers et al. 1994, Burgess and Wetzel 2002).

Windthrow of some residuals in the first five years after harvest can be expected when using the clearcut with seed tree system, but silvicultural efforts and careful tree marking can minimize these losses (Stathers et al. 1994, Everham and Brokaw 1996). Wind stability of trees increases with time after partial cutting as crown closure occurs and swaying and mechanical stresses near the stem base lead to preferential carbon allocation to this bole location (Stathers et al. 1994, Bevilacqua et al. 2005).

Shelterwood is the recommended silvicultural system to promote natural regeneration of white and red pine in stands with 12 m^2 ha^{-1} or more white and red pine basal area. Application of the shelterwood silvicultural system involves a sequence of two to four partial harvests depending on the current age of the stand (Figure 30). Only two cuts are done in stands that are made up of a few but large white and red pine; the regeneration cut and the final removal cut:

- The initial *preparatory cut* is usually applied to

Figure 29. Mixed pine stand in Regan township in the Romeo-Malette forest management unit using the clearcut with seed tree silvicultural system showing overstory white pine that were preferentially retained as seed trees. (Photo by S. McPherson)

stands 61 to 80 years old to remove undesirable, defective, suppressed trees (i.e., those typically killed by natural surface fires) and to enhance crown development of trees retained for their vigour, form, and seed production potential. The crown closure target for these cuts is 50%.

- The *regeneration cut* is applied to stands that are 80 to 100 years old, again retaining a well-spaced canopy of the best seed trees to achieve a crown closure of 40 to 50%. White pine is the preferred residual canopy species, but red pine and white spruce can also be retained to achieve necessary spacing and crown closure where suitable white pine are lacking.
- The *removal cut* is applied when white pine regeneration is well established (i.e., minimum of 40% stocking or 1,000 stems ha^{-1} of target species) and can be done in one or two steps. A first removal cut is applied to stimulate height growth of previously established white pine regeneration. The crown closure target for a first removal cut is 30 to 40%. Where white pine regeneration is well established and of sufficient size and density to create a fully stocked stand (e.g., minimum of 350 well distributed white and red pine saplings per hectare 5 to 6 m tall),[44] a final removal cut is applied. At final removal, at least ten large, healthy veteran trees per hectare are retained to meet ecological objectives (OMNR 2004d).

The time between successive harvests is dependent on the density and size (and therefore, growth rate) of established white pine regeneration. In most cases, uncut/unmanaged white pine stands have insufficient

Figure 30. White pine stand in the Nipissing forest management unit managed using the uniform shelterwood silvicultural system. This photograph shows stand structure following a regeneration cut. (Photo by B. Parker)

advance regeneration present, and a combination of partial harvesting and silvicultural intervention is required to establish natural and/or artificial regeneration (see following section).

The recommended level of crown closure of 40 to 50% in the regeneration cut of shelterwoods represents a balance between providing a suitable environment for the establishment, growth, and survival of white pine, while reducing the incidence of weevil damage and infection by blister rust. The residual overstory retains a large number of good seed-producing trees, and creates a moderate, partially shaded understory environment that favours seed germination and early seedling establishment (see Section 3.4). Moderate shade also maximizes white pine seedling height growth and helps the white pine regeneration to maintain a favourable vertical position relative to competing species in the developing understory canopy (Figure 31) (OMNR 1998a, Burgess and Wetzel 2002).

When selecting trees to remove or retain in partial harvest systems on all Crown forests in the GLSL forest

[44] Nipissing Forest FMP (2004)

Figure 31. Abundant white pine advance regeneration in the understory of a white pine stand after partial harvesting in the Kirkwood Forest, north of Thessalon, ON. (Photo by S. McPherson)

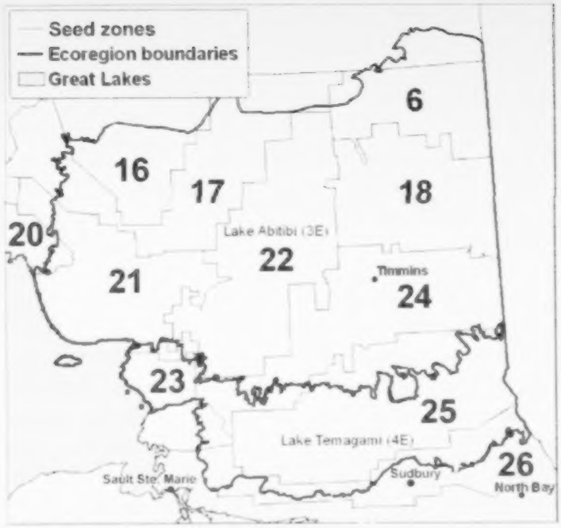

Figure 32. Ten of Ontario's 38 seed zones fall within ecoregions 3E and 4E.

region, MNR's tree marking guidelines (OMNR 2004d) must be applied. These guidelines were developed to prevent high-grading and the erosion of the genetic diversity of Crown forests and to retain suitable numbers of trees for wildlife (OMNR 1995, OMNR 2004d). Keeping the best canopy trees as a seed source in seed tree and shelterwood applications helps to ensure that the genetic diversity of regenerating trees is not degraded or compromised by management. In smaller, isolated[45] white pine stands, inbreeding can be minimized and genetic diversity maintained by retaining a breeding population of at least 100 canopy trees until the stand is successfully regenerated (OMNR 1998a).

Genetic variability is also conserved through requirements for using local seed sources for seedling stock production (Figure 32) (OMNR 1998a). As well, use of planting stock is restricted to the seed zone from which it originated to ensure that artificial regeneration is genetically adapted to the local climate.

Silvicultural treatments to secure regeneration

The silviculture guide pertaining to white pine (OMNR 1998a) identifies a number of acceptable treatment options for *site preparation*, *regeneration*, and *stand tending* (including competition control) that can be used to aid the early establishment, growth, and survival of white pine regeneration (Wagner and Colombo 2001).

[45] More than 1 km from the nearest white pine stand

Site preparation

Site preparation refers to treatments that modify the site to be regenerated to create a more favourable environment for early establishment of natural or artificial regeneration (OMNR 1998a, Wagner and Colombo 2001). Three approaches may be used alone or in combination depending on silvicultural objectives and economic and social considerations (OMNR 1998a, Burgess and Wetzel 2002). *Mechanical site preparation* (e.g., scarification) is achieved using heavy equipment designed and operated to disturb/remove the forest floor organic layers both to improve the seedling environment and reduce the abundance of competing plant species. *Chemical site preparation* relies on the use of herbicides to slow the rate of regrowth of understory vegetation, but does not physically disturb the forest floor. *Prescribed burning* refers to the use of low intensity surface fire to consume logging slash and much of the L and F layers of the forest floor, and reduce understory competition. Prescribed burning prior to or after partial harvesting can be applied without causing major crown scorching and mortality of mature pine trees (Van Wagner and Methven 1978, McRae et al. 1994) (see Section 3.3).

Mechanical site preparation and prescribed burning are the preferred options for natural regeneration as they create optimal seedbeds for white pine. However, prescribed understory burning is only a *conditionally recommended* practice for natural and artificial regeneration of white pine in Ontario's GLSL forests (OMNR 1998a). Chemical site preparation, which does

not provide suitable seedbed, is more commonly used prior to planting. Combined mechanical and chemical site preparation is the most effective approach to promote natural regeneration and control competing vegetation (Struik 1978, Burgess and Wetzel 2002).

Regeneration

White pine can be naturally or artificially regenerated (Figure 33). In either case, careful planning of regeneration and associated silvicultural treatments is needed to successfully establish required densities of healthy seedlings. When using natural regeneration, site preparation to create seedbed must coincide with the occurrence of bumper seed crops to obtain desirable stocking (Horton and Bedell 1960, Zenner and Krueger 2006). As a result, reliance on natural seeding to regenerate white pine is limited to the 3- to 10-year cycle of above average seed production.

By comparison, planting is not restricted to good seed crop years. However, artificial regeneration does depend on bulk seed collections within climatically based provincial seed zones to produce genetically adapted planting stock. Seed collection is largely confined to bumper crop years and requires that adequate seed is available to meet the stock production and planting needs of intervening years. The comparatively large initial size of planted seedlings provides artificial regeneration with an early advantage in competing with understory vegetation for resources and growing space (Burgess and Wetzel 2002) (Figure 34). High quality vigourous planting stock, as well as careful handling and planting of this stock, can also increase seedling survival and growth (OMNR 1998a).

Figure 33. *White pine artificially regenerated by planting in Ecoregion 3E. (Photo by S. McPherson)*

Stand tending

Stand tending is used to ensure the continued growth of newly established seedlings and includes the control of competing vegetation. Vegetation management treatments are applied to reduce the abundance of competing plant species, increase resource availability, and improve the environment for crop tree growth. Herbaceous vegetation is a strong early competitor of white pine and other conifer species, with the inhibitory effects of woody competition generally increasing over the first five growing seasons (Wagner et al. 1999, Pitt et al. in press). Since white pine seedlings grow relatively slowly for the first five years, early vegetation control by chemical, mechanical, or manual methods is critical (OMNR 1998a, Burgess and Wetzel 2002, Pitt et al. in press). Although young white pine shows a positive growth response to release from competition (Wendel and Smith 1990, OMNR 1998a), early growth losses resulting from delays in competition control cannot be recovered (Wagner et al. 1999, Pitt et al. in

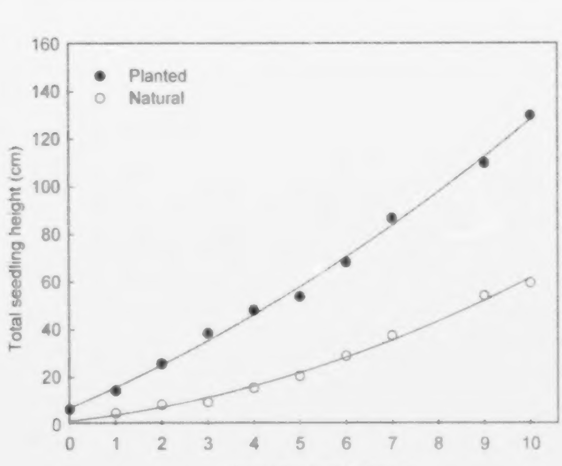

Figure 34. *Comparative 10-year height growth response of naturally regenerated and planted white pine in a uniform shelterwood that received mechanical site preparation. Height at year 0 for planted pine refers to mean height of planting stock. (Morneault and Parker, unpublished data)*

press). For this reason, chemical site preparation before seedlings are established is preferred to delayed use of herbicides for initial competition control (Wagner and Colombo 2001, Thompson and Pitt 2003). This approach has the added advantage of minimizing potential herbicide damage to young white pine regeneration, which has been observed in some studies (Morneault et al. 2003).

Tending to control competition is applied to maintain understory light conditions near 50% sunlight to maximize height growth, while minimizing damage by white pine weevil and blister rust (Katovich and Mielke 1993, OMNR 1998a, Messier et al. 1999). While moderate shade reduces volume and diameter growth, height growth is maximized and enhances canopy recruitment of pine regeneration. In plantations and clearcuts with seed trees where light levels are relatively high, aggressive shade-intolerant species (e.g., aspen, bracken fern, and grasses) rapidly colonize the site, overtop pine seedlings, and compete for water, nutrients, and light, necessitating early competition control (OMNR 1998a, Burgess and Wetzel 2002, Thompson and Pitt 2003). Under the shelterwood silvicultural system, maintaining moderate overstory shade (~ 40 to 50% sunlight) may slow the establishment and growth of shade-intolerant species but control of both shade-intolerant and -tolerant species (e.g., balsam fir, beaked hazel) is still necessary to improve growth of pine regeneration (OMNR 1998a, Krueger and Puettmann 2004, OMNR 2004d).

Silvicultural treatments to improve stand growth and quality

Stand improvement cutting (e.g., overstory release), thinning, and pruning are also listed as tending options in MNR's silviculture guides (OMNR 1998a). Commercial thinning and stand improvement cutting treatments are applied at intermediate and later stages of stand development to selectively remove non-desirable species or defective, suppressed trees with the purpose of improving the growth, quality, and value of the residual white pine stand. White pine is well suited to these treatments because it can respond to partial cutting and release from competition (Wendel and Smith 1990) even when more than 100 years old (Anderson et al. 2002, Bebber et al. 2004, Zenner and Krueger 2006). Pruning of lower branches can reduce the number and size of knots, thereby increasing the yield of higher grade lumber produced (Calvert and Brace 1969, Seymour 2007). While these stand tending options require additional silvicultural investment and are seldom used operationally in Ontario, they are discussed briefly below because of their potential to increase the production of high quality logs that are traditionally in demand.

Overstory release cuttings

In the GLSL forest region, white pine often colonized the understory of shade intolerant stands that developed following stand-replacing fire, eventually attaining canopy dominance where the natural fire interval allowed (see Section 3.3) (Frelich 2002). Exploitive logging in the early 20th century also initiated this successional sequence where sufficient white pine seed trees were present after harvest. These two-storied mixedwood stands are common throughout the commercial range of white pine in eastern Canada and are excellent candidates for full or partial overstory cutting (i.e., stand improvement) treatments to release white pine and accelerate natural succession. Overstory release cutting can increase diameter growth of the remaining stems and thus total and sawlog volume production of white pine (Buckman and Lundgren 1962, Stiell et al. 1994, Puettmann and Saunders 2000). In a study established at the Petawawa Research Forest, ON, within 30 years following complete removal of an 80-year-old aspen and white birch canopy to release 55-year-old white pine, diameter, total sawlog (trees >17 cm dbh) volume production, and the number of large diameter white pine trees increased significantly relative to control stands (Bevilacqua et al. 2005, Burgess et al. 2005).

Thinning

White pine has traditionally been managed at relatively high density to achieve maximum stand volume yield (Barrett et al. 1976, Seymour 2007). However, thinning of immature forest stands to manipulate the dynamic relationship between stand density and tree size can be applied to better balance total volume production with individual tree growth while improving the value and quality of the residual crop trees (Smithers 1954, Drew and Flewelling 1979, Seymour and Smith 1987, Smith and Woods 1997, Seymour 2007). Because crown size is strongly related to diameter growth, thinning to reduce crown competition among neighbouring dominant and codominant potential crop trees results in the greatest residual tree diameter and volume growth response (Smithers 1954, Gillespie and Hocker 1986a, Seymour and Smith 1987). As well, periodic thinning provides an opportunity to harvest merchantable fibre that would otherwise be lost to mortality by self-thinning (Smithers 1954, Gillespie and Hocker 1986b, Burgess and Robinson 1998).

Thinning of white pine plantations and natural stands can increase the growth rate and value of the residual stand, and reduce the length of the technical rotation to attain some minimum acceptable product size (Smithers 1954, Leak 1986, Gillespie and Hocker 1986b, Burgess and Robinson 1998, Anderson et al. 2002). Long-term studies of natural white and red pine stands in Ontario have demonstrated that thinning can be used to concentrate growth on selected crop trees and increase the relative proportion of valuable, large diameter trees in the stand (Smithers 1954, Burgess and Robinson 1998). Opinions vary on the density at which white pine should be managed, and depend in part on the desired final product (Leak 1986, Hibbs and Bentley 1987, Burgess and Robinson 1998, Seymour 2007). When managing for sawlog production, Smithers (1954) recommended a series of frequent (every 5 to 15 years) light thinnings (<30% basal area removed) beginning before competition reduces crown size to the point where a positive diameter response to stand density reduction no longer occurs (i.e., when the crown occupies less than 30% of total tree height). Alternatively, somewhat heavier thinning can improve individual tree size without significantly sacrificing total stand yield (Seymour 2007). Ultimately, forest managers must select a thinning scenario based on the relative advantages and disadvantages of each relative to prospective markets, the economic investment required, and management objectives for a given stand (Leak 1986, Hibbs and Bentley 1987). Density management diagrams produced for white pine in Ontario are available to assist with planning of thinning operations (Smith and Woods 1997).

Pruning

White pine has its greatest economic value when managed for production of quality, high grade lumber (Seymour 2007). However, its natural self-pruning of lower branches is relatively slow, which results in many knots on the lower 5 m of the bole. This portion of the stem contains only a third of the volume, but about two-thirds of the lumber value (Stiell 1959). As a result, pruning is imperative when intensively managing white pine stands for production of high quality lumber, but is otherwise unprofitable unless used to reduce blister rust infection (Smith and Seymour 1986, Seymour 2007). The greatest value is achieved when pruning is coupled with thinning (Smith and Seymour 1986, Page and Smith 1994) and the largest economic returns are gained when stands thinned heavily enough to eliminate crown competition are pruned (Page and Smith 1994, Seymour 2007).

A number of pruning protocols have been proposed (e.g., Stiell 1959, Calvert and Brace 1969, Smith and Seymour 1986, Page and Smith 1994). In general, pruning is confined to the lower 5 m of the fastest growing trees with straight stems. To avoid diameter and height growth losses, restrict pruning to the lower half of the tree's total height. Only the smaller diameter live branches (<5 cm) are removed, and those are cut as close to the main stem as possible to reduce the time needed for wound healing and to minimize potential infection by wood decaying fungi. Pruning should begin before significant self-pruning occurs because dead branches form loose knots that degrade lumber quality and provide entry points for decay fungi (OMNR 1998a).

Silvicultural management of white pine weevil and blister rust

Management of damage by weevil and blister rust is implicit to decisions about silvicultural approaches to regenerate and grow white pine. Because these silvicultural approaches are based on knowledge of the life cycle and biology of these two damaging agents and aimed at creating a microenvironment unfavourable for their development and spread, they are discussed briefly below by way of introducing silvicultural control options.

White pine weevil

Life cycle and biology of white pine weevil

Adult weevils overwinter in the lower, more decomposed F and H forest floor litter layers, and prefer warmer, drier sites (MacAloney 1930, Sullivan 1961). They emerge in the spring and crawl or fly to tops of white pine saplings, where they puncture and feed on the bark and cambial tissues of the previous year's terminal shoot. The adult weevils mate in late spring and females may lay up to 200 eggs in their feeding holes over a six-week period. When the eggs hatch about two weeks later, the larvae begin to feed on cambial tissues until late summer, when they emerge as adults, continue to feed, and move to overwintering habitat at the onset of cold weather (Sullivan 1961, Szuba and Pinto 1991) (Figure 35). If enough larvae are present, the terminal shoot can be girdled and killed. Frequency of weevil injury varies with time, primarily as a function of population size, with smaller, less desirable host trees subject to increased frequency of attack as weevil populations grow (Marty and Mott 1964) (see Section 3.6.1).

Figure 35. *Weevil larvae feeding on the cambial tissues of the terminal shoot of a white pine sapling. (Photo by S. McPherson)*

Figure 36. *Damaged terminal shoot of an open-grown white pine seedling. (Photo by D. Pitt)*

Damaged leaders are easily spotted in early to mid-July, as they wilt, bend over, and form the "shepherd's crook" characteristic of weevil attack (Figure 36). Loss of apical dominance causes one of the lateral branches of the whorl below the dead leader to eventually become the new terminal shoot. This loss of dominance results in the formation of a prominent stem crook or, where two lateral branches become dominant, a fork.

Evidence of the influence of soil factors on incidence of weevil damage is conflicting. Plantations growing on soils with restricted drainage (Connola and Wixson 1963, Lavallée et al. 1996) and those established on warmer, drier sites (MacAloney 1930, Dirks 1964) were reported to be more susceptible to weevil attack. As well, all other factors being equal, soil and site conditions that are favourable to white pine growth and formation of larger diameter leaders are likely to result in higher levels of weevil attack (MacAloney 1930).

Silvicultural control of white pine weevil damage

The higher light and temperature, lower humidity, and thicker terminal shoots that occur on exposed, more open environments promote the feeding, oviposition, and development of white pine weevil (Sullivan 1961, Szuba and Pinto 1991). Silvicultural approaches to create moderate shade (40 to 50% sunlight) are recommended to minimize weevil damage without causing significant white pine volume growth losses (Patterson and Aizen 1989, deGroot et al. 2005, Pitt et al. in press). Stiell and Berry (1985) concluded that 50% to 75% sunlight will result in acceptable levels of weevil damage, accelerate height growth, and shorten the period needed for pine regeneration to attain 5 m in height, above which the likelihood of weevil attack declines. However, even where pine is heavily shaded, growth losses should be weighed against the losses in volume and lumber quality that result from uncontrolled weevil damage under more open conditions (Brace 1971).

Where restoration using plantations is a primary objective, weevil damage can be reduced by manipulating stand density and/or through mixed species plantings. Intraspecific competition in higher density (spaced < 2m x 2m) white pine stands reduces weevil damage by inhibiting leader diameter growth so that fewer trees are suitable to the weevil (Belyea and Sullivan 1956). Tighter spacing also enhances natural replacement of damaged terminals by lateral branches (MacAloney 1930, Pubanz et al. 1999). These denser stands also attain crown closure more rapidly, creating shade that inhibits weevil attack and provides less desirable overwintering habitat (Hodge et al. 1990). Effective management of high density stands will require pre-commercial thinning when trees are 5 m in height to improve volume growth, but allow for the selection of 200 to 400 white pine crop trees per

hectare that best meet management objectives (Dirks 1964, Stiell 1985, Pubanz et al. 1999). Mixed-species plantations can also be used to reduce white pine leader diameter and weevil damage while maintaining acceptable growth, provided the "nurse crop" species is more shade intolerant, grows faster, and casts moderate shade (~50% sunlight) on the neighbouring rows of white pine (MacAloney 1930, Katovich and Mielke 1993, OMNR 1998a, deGroot et al. 2005).

Underplanting white pine in hardwood, mixedwood, or conifer stands also provides moderate shade needed to reduce weevil damage without unacceptable growth loss (Szuba and Pinto 1991, Katovich and Morse 1992, Lavallée et al. 2001, deGroot et al. 2005, Major et al. in press). When white pine reaches 5 m in height the chance of weevil attacks decreases and the overstory should be removed or thinned to promote white pine diameter and volume growth. Side shade in strip cuts in conifer-dominated stands can also reduce weevil damage while maintaining acceptable growth of planted white pine. Strip cuts 3 m wide separated by uncut canopy strips 5 m wide were recommended by Messier et al. (1999), while Stiell and Berry (1985) suggest north-south strips with a width of 0.7 to 1.0 times stand height.

Shelterwoods are the best option for controlling weevil damage (Katovich and Mielke 1993, OMNR 1998a, deGroot et al. 2005) because the moderately shaded understory reduces leader size and weevil damage of white pine without compromising height growth potential (Szuba and Pinto 1991, Katovich and Mielke 1993, OMNR 1998a). These stands also provide habitat for many natural predators that may consume 30% of yearly adult and larval stage weevil populations (MacAloney 1939, Belyea and Sullivan 1956), including black-capped chickadees (*Parus atricapillus* L.), downy woodpeckers (*Picoides pubescens* L.), several small mammals, and the larva of a fly species (*Lonchea corticis*) (Szuba and Pinto 1991, OMNR 1998a). Retention of cavity trees and coarse woody debris during harvest operations is recommended to provide habitat for natural predators of the weevil (OMNR 1998a).

In regenerating stands affected by weevil, corrective pruning of infested, damaged leaders can reduce weevil populations and increase the rate at which a lateral branch becomes the new terminal shoot (Belyea and Sullivan 1956, Katovich and Mielke 1993). As well, prompt and repeated pruning of infested leaders for the first 15 to 20 years can minimize the adverse effects of repeated weevil attack on merchantable height, volume growth, and wood quality. This ensures production of good quality sawlogs in the first 5 m of the bole but the cost must be weighed against value derived (Dirks 1964). After removal of infested leaders, treatments are needed to kill and reduce the weevil population to decrease the potential for further damage (Hodge et al. 1990).

White pine blister rust

Life cycle and biology of white pine blister rust

This disease has a fairly complex life cycle involving five spore stages and two plant hosts, species of the *Ribes* genus (gooseberries, currant) and white pine (or other five-needle pines) (OMNR 1998a). Fungal basidiospores formed on the *Ribes* leaves are aerially dispersed and enter white pine through the needles in August to October in the presence of free moisture (i.e., dew, raindrops). Basidiospores are fragile and short-lived, and quite sensitive to desiccation and sunlight. As a result, viable spores are generally only dispersed up to 300 m, but under appropriate conditions may travel several kilometres. The production, dispersal, germination, and infection of white pine requires a minimum period of 48 hours at 100% humidity, free moisture on needles, and air temperatures <20°C. The spores germinate and the fungus enters needles through the stomata, then grows through the needles, twigs, and branches over a 12- to 18-month period. Within three to six years of infection, the cambial tissues within the branches and stems are killed. In seedlings and saplings, the main stems are usually girdled and killed, while in large diameter trees only branches may be killed. Slight swelling followed by formation of lesions or "bark blisters" occur at these infection sites. Rupture of these blisters in the spring months initiates the dissemination of spores that are carried by wind up to hundreds of kilometres to *Ribes* plants, and the cycle is repeated (Figure 37).

Silvicultural control of blister rust

Meteorological and physiographic factors strongly influence the distribution of blister rust and the general risk of infection at the macro scale. Risk of infection increases with latitude, elevation, and proximity to large, cold water bodies (Van Arsdel 1961). These relationships have been used to develop broad regional hazard zones for blister rust infection, with the level of silvicultural intervention required to prevent mortality increasing with the risk of infection (Gross 1985a, White et al. 2002, Katovich et al. 2004, Van Arsdel et al. 2006). Four broad geographic blister rust hazard zones (i.e., low, intermediate, high, and severe) were identified in

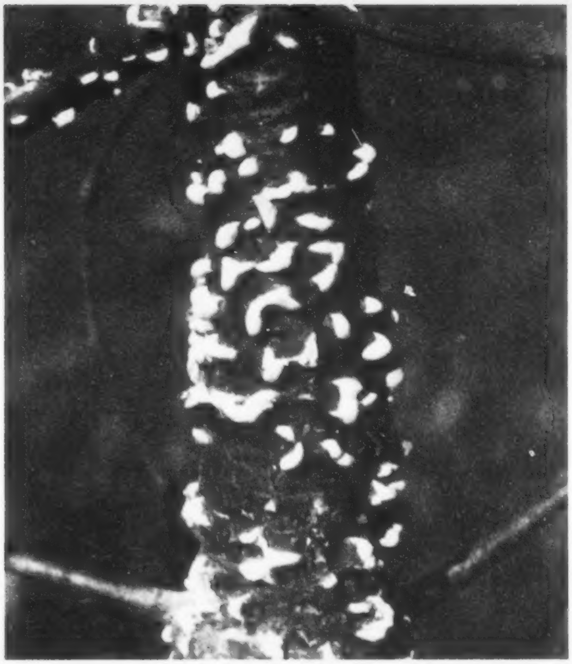

Figure 37. Blister-like spore fruiting bodies emerging from stem canker on a white pine sapling infected with blister rust. (Photo from S. Greifenhagen)

Ontario (Gross 1985b, Hodge et al. 1990). Ecoregions 3E and 4E fall within the severe hazard zone because the cooler, more humid climatic conditions of this region are generally favourable for blister rust spread, infection, and completion of the fungi's life cycle (Gross 1985b). Most areas within this severe hazard zone have extremely high levels of infection and mortality, with white pine regeneration possible on only a small proportion of sites unless young seedlings are grown beneath an overstory canopy or lower branches are pruned (Gross 1985b).

Within a hazard zone, the incidence of infection can vary considerably due to the influence of vegetation and local topography on dew and fog formation and rate of needle drying (Hodge et al. 1990, White et al. 2002). Stand and site features that create a microenvironment conducive to infection include: (1) depressions, valleys, lower and north-facing slopes, (2) fresh to moist soils, (3) proximity to water bodies, (4) dense understory vegetation, (5) open areas without an overstory canopy, and (6) small canopy openings with a diameter less than the height of the surrounding trees (Van Arsdel 1969, Hodge et al.1990). Therefore, both regional and local features that influence infection should be considered when rating reforestation sites for risk of damage by blister rust, particularly where restoration using plantations is the objective.

Blister rust infection of white pine regeneration is much less frequent in uncut and partially cut stands where the presence of an overstory canopy decreases dew formation in the understory (Hodge et al. 1990, Katovich and Mielke 1993, White et al. 2002). The presence of an overstory also contributes to reduced abundance of shade intolerant *Ribes* plants. Planting white pine under an aspen, white birch, jack pine, or red pine canopy can reduce rust infection and may provide an alternative to plantations as a restoration method (Katovich and Meilke 1993, deGroot et al. 2005). Silvicultural control of blister rust is much less ardous in white pine-dominated stands where uniform shelterwoods provide the residual canopy needed to both regenerate white pine and reduce the rate of rust infection and damage (Katovich and Mielke 1993). Unfortunately, little scientific information is available to guide the operational use of partial harvesting systems to decrease the incidence of blister rust (Katovich and Mielke 1993, Katovich et al. 2004).

White pine plantations are particularly vulnerable to infection as their microclimate results in dew formation, a key factor needed for infection (Katovich and Mielke 1993). A number of silvicultural approaches have been used to control blister rust in plantations with varying levels of success. Early historical control efforts focused on eradication of wild and cultivated *Ribes* sp. to eliminate its alternate host (Anderson 1973). Although this may sometimes be an effective means of decreasing infection, it is difficult and costly to apply. For high-value plantations, seed orchards, or nurseries, eradication can contribute to blister rust control and involves removing all *Ribes* within 300 m of the area to be protected (Van Arsdel 1969, Hodge et al. 1990, deGroot et al. 2005). In many instances, local *Ribes* eradication is ineffective due to the long distances that spores may disperse (Anderson 1973).

Repeated pathological pruning of infected branches will likely be needed in plantations to reduce damage and mortality. Regular preventative pruning of uninfected branches from the basal 2 m of the main stem (up to 50% of stem length), the primary site of infection, is also an effective but labour intensive method of reducing infection and damage in young plantations (Hodge et al. 1990, Hunt 1991). The intensity of pruning efforts should increase with risk and level of infection based on management objectives and other considerations. Generally, where infection is high, pruning should be applied to all trees or, where that is not feasible, confined to a desired number of selected crop trees (Hodge et al. 1990).

Timely, effective tending to control competition is essential to white pine management, and may help reduce infection by blister rust. Vegetation control is thought to improve air circulation and the drying of lower branches of white pine, thereby reducing the likelihood of spore germination (Krueger and Puettmann 2004). Vegetation control also removes existing *Ribes* plants.

Chemical control options for blister rust are limited, although systemic and foliar application with fungicides containing triadimefon can afford short-term early protection from infection (Bérube 1996, Pitt et al. 2006). In the longer-term, the development of genetically resistant varieties or hybrids of white pine has the greatest potential for reducing damage by blister rust, but these are not yet available (see Section 7.3.5) (Hunt 2003, Daoust and Beaulieu 2004, Lu et al. 2005).

7.2 Provincial parks and conservation reserves

Through its recent land use strategy (OMNR 1999, Bell et al. 2000), the MNR has set aside an additional 2.4 million ha[46] of Crown forest land for protection under the *Provincial Parks and Conservation Reserves Act* for a total of 9.3 million ha or 8.7% of the total area of Crown forest land (OMNR 2007b). Relatively less white and red pine forests are conserved in Ecoregion 3E (372 ha, or 6.5% of the total PRW forest type) than in Ecoregion 4E (49,754 ha, or 18% of the total PRW forest type) (Figure 38). These protected areas are mostly older, mature and old growth stands, with the exception of a relatively large percentage of stands of the PRW forest type in the sapling stage in Ecoregion 3E (Figure 39). However, protection of existing old growth white pine forests without a reintroduction of fire disturbances (i.e., prescribed burning), or other management practices that emulate the ecological effects of fire, will eventually lead to natural succession to forest types dominated by more shade-tolerant tree species (McRae et al. 1994, Voras 1994, OMNR 2004b, Van Sleeuwen 2006).Parks and protected areas have management plans separate from FMPs.

7.3 Putting policy into practice

Where white pine occurs in ecoregions 3E and 4E, 15 SFL holders are currently operating and their objectives and approaches to white pine management are outlined in their FMPs. Some have elaborated on these objectives in specific, more detailed white pine management strategies[49] and/or as part of old growth management strategies that address the requirements MNR's old growth policy.[50] The components of these

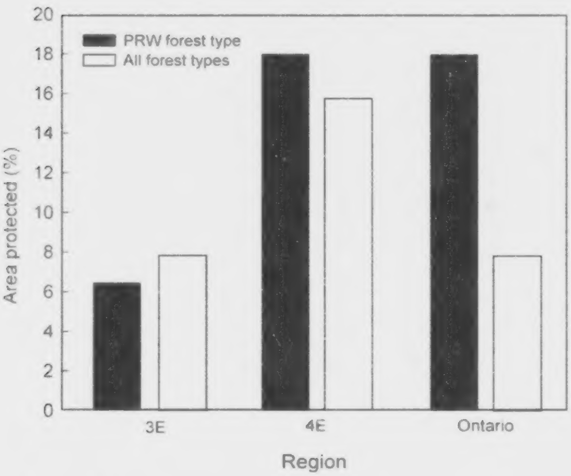

Figure 38. *Proportion of white and red pine forest type (PRW) currently protected in ecoregions 3E and 4E and Ontario as a whole, relative to the proportion of all forest types protected.*[47]

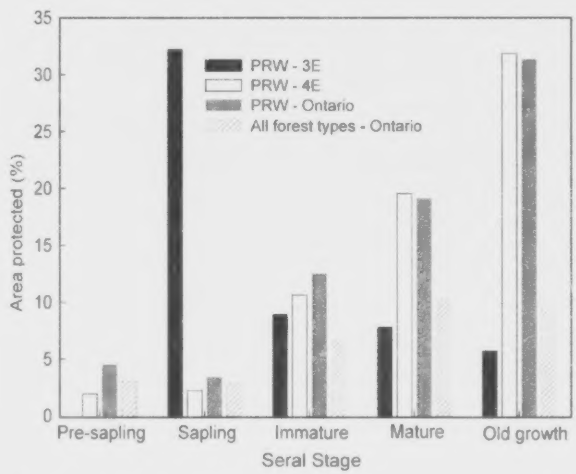

Figure 39. *Proportion of protected area of white and red pine forest type (PRW) in Ecoregion 3E, Ecoregion 4E, and Ontario as a whole by stand seral stage, compared with proportion of area of all forest types protected in Ontario.*[48]

[46] http://crownlanduseatlas.mnr.gov.on.ca/supportingdocs/alus/landuse2.htm#table1
[47] Data from the FRI compiled for the State of the Forest Report 2006 (OMNR 2007b)
[48] Data from the FRI compiled for the State of the Forest Report 2006 (OMNR 2007b)
[49] e.g., Pineland and Romeo-Malette FMUs
[50] e.g., Nipissing and Sudbury FMUs

plans vary among FMUs depending on site, stand, and landscape conditions as well as white pine old growth and restoration targets.

7.3.1 Old growth targets

Old growth white pine forests are rare in Ontario and will require special effort to ensure their continued presence on the landscape through both conservation of existing and creation of new stands. A combination of conservation and site- and stand-specific management can be used to maintain existing old growth white pine stands in the short-term (Barnes 1989, Voras 1994). However, windthrow, insects, disease, and wildfire are a continuous threat to most existing old growth, so protected status by itself is likely insufficient to secure its future. As well, successional replacement by shade-tolerant species is a threat to these forests but could be minimized by use of prescribed burning and other practices (Barnes 1989, McRae et al. 1994). Management intervention can also play a role in creating new old growth forests or more forests with old growth attributes. Variable density thinning and variable retention (or structural retention) harvesting to retain appropriate residual trees can be used to increase the structural complexity and accelerate the development of old growth forest attributes of managed stands, while removing some merchantable timber (Voras 1994, Franklin et al. 1997, Burton et al. 1999, Pinto 2003, Bebber et al. 2005, Gilmore and Palik 2005). Alternatively, extended rotations of a portion of managed white pine forests have been proposed as a mechanism to create new areas of old growth (Figure 40) (Voras 1994, Burton et al. 1999).

In Ontario, as a minimum, SFL holders are required to ensure that the age-class structure of white pine forests in their FMU maintains old growth white and red pine forests. Specific old growth objectives in each FMU of ecoregions 3E and 4E are based on historic, current, and future desired forest conditions. For example, the most recent Nipissing Forest (2004) and Sudbury Forest (2005) FMPs call for a doubling in the amount of old growth within 100 and 45 years, respectively.[51]

The extent of pre-industrial old growth white pine forest that existed in Ontario is unknown. Sustainable forest licence holders have used two indirect methods to estimate this area (i.e., historic forest condition) to assist

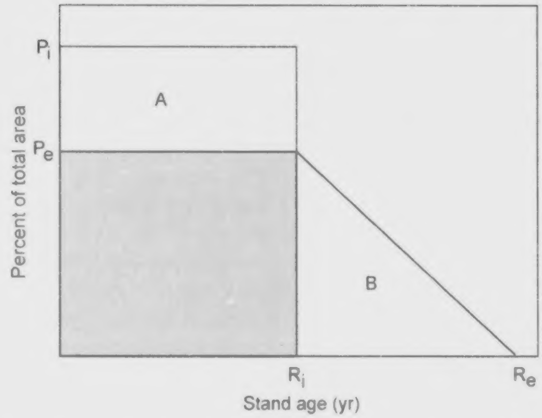

***Figure 40**. Illustration of hypothetical management approach to maintain old growth forests by harvesting a portion of the landscape at times beyond a fixed industrial rotation (R_i). A portion of the land base (i.e., Pi - Pe) that would normally be harvested under an industrial rotation (Area A) is allowed to grow to an extended rotation age (R_e) (Area B), where P_i and P_e represent the portion of the landscape managed under an industrial and extended rotation, respectively. (Adapted from Burton et al. 1999)*

them in establishing old growth targets as part of the forest management planning process.[52] The first method uses MNR's Strategic Forest Management Model's (SFMM)[53] natural benchmarking (NB) scenario, which forecasts the amount of old growth that would result on a given landscape subjected to a given fire regime, without human intervention (i.e., no fire suppression or management). The other method uses fire history information and a negative exponential fire frequency model to derive the hypothetical age structure of an umanaged forest resulting from a given stand-replacing fire regime (Section 3.3) (Johnson and Van Wagner 1985, Johnson and Gunsell 1994).

One persistent issue debated by the public, local citizens committees,[54] and independent forest auditors concerning old growth forests is whether existing provincial parks and conservation reserves within FMU boundaries should count towards future old growth targets. Specifically, the concern is whether these protected areas will form the majority of old growth forests on the landscape, with little effort made by SFL holders to create additional old growth forests on their FMUs.[55] These protected areas were originally established to ensure the best remaining old growth stands received the highest level of protection. If protected areas are not included in meeting these

[51] The current and future area of old growth forest can be obtained for each FMP by contacting the SFL forester or MNR's regional planning analyst in the Northeast Region.
[52] SFLs in ecoregions 3E and 4E have used one or both methods in their current FMPs.
[53] Strategic Forest Management Model (Davis 1999)
[54] For example, refer to Sudbury Forest IFA (2001)
[55] Sudbury Forest IFA (2001), Nipissing Forest IFA (2006)

targets, SFLs will be required to generate old growth from a larger proportion of PRW stands being managed for timber. At present, the old growth policy stipulates only that SFL holders must maintain old growth across the forest landscapes in their FMU (OMNR 2003a).

7.3.2 Restoration targets

Within ecoregions 3E and 4E, all SFL holders acknowledge the historical decrease in the abundance of white and red pine and almost all have included increasing the area of the PRW forest type as an objective in FMPs. To identify specific targets, data from Crown land surveys are used to estimate pre-settlement levels of white and red pine forests (Jackson et al. 2000, Pinto et al. 2008). Where this information is not available, more general objectives are established to increase the amount of pine forest within a specific timeframe. Some examples include the intent to double the area of white pine forests in the next 50 years and to restore 40 to 50 ha of white pine forest each year.[56]

The minimum objective of all white pine management strategies is to maintain the total area of future white pine forest condition above 1995 levels (OMNR 2003a). Where re-establishment of white pine on harvested areas may be difficult, alternative areas with a higher probability of successful regeneration may be selected. Most SFL holders focus their restoration efforts on stands with low white pine stocking or where white pine is suspected to have grown in the past. White birch, mixedwood, or aspen stands with scattered white pine or old white pine stumps are viewed as good candidates for establishing white pine forests[57] (Figure 41).

Restoring white pine using plantations is relatively expensive, requiring repeated intensive silvicultural interventions to promote survival and growth and to protect regeneration from blister rust and weevil (Burgess et al. 1995, Pitt et al. in press). To minimize renewal costs and increase chances of success, restoration using plantations may be confined to less productive, less competitive sites in areas where the risk of white pine blister rust infection is relatively low. In stands where white pine is a minor component of the overstory, partial harvesting to create moderate shade in combination with underplanting of white pine is sometimes used for restoration.[58] Some SFLs

Figure 41. Restoration efforts can be focused on stands that are known to have previously supported white pine, as indicated by stumps such as those illustrated in above photograph from Samuel de Champlain Provincial Park, ON. (Photo by C. Latremouille)

acknowledge that white pine existed more as scattered individuals in pre-settlement times in their FMU and plant white pine seedlings in mixtures with other species.[59] Where acceptable white pine advance regeneration occurs, careful partial harvesting to protect this regeneration from logging damage may be considered. In some northern FMUs in Ecoregion 3E with relatively little white pine, these few stands are not harvested[60] at all or only in case of special request from local industry (e.g., for local log building contractors).[61] In the latter scenario, a minimum of 50% of the white and red pine stems may be left on site, and silvicultural practices to regenerate these species applied.

7.3.3 Frequency of use of different silvicultural options

Over the past 30 years, management of white and red pine forests in Ontario has increasingly relied on even-aged silvicultural systems that retain a portion of the overstory canopy. This is the result of accumulated operational experience, increased knowledge of pine ecology, and the public's concerns about conventional clearcutting of old growth white and red pine forests. In ecoregions 3E and 4E, the uniform shelterwood system was used in 70% of the 13,300 ha of PRW stands harvested from 1996 to 2005 (Figure 42); some form of clearcutting (i.e., clearcut, clearcut with standards, clearcut with seed trees) was used on the remaining 30%. About 7% (895 ha) of the area harvested in this period was in Ecoregion 3E, of which the shelterwood

[56] Timiskaming Forest FMP (2006) and Romeo Malette Forest FMP (2006), respectively
[57] Pineland Forest FMP (2006), Romeo Malette Forest FMP (2006)
[58] Timiskaming Forest FMP (2006), Superior-Martel Forest FMP (2006)
[59] Nighthawk Forest FMP (2003)
[60] Nighthawk Forest FMP (2003)
[61] Romeo Malette Forest FMP (2006)

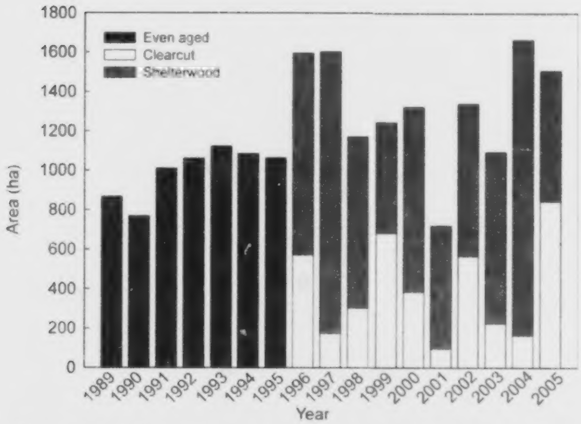

Figure 42. Area of white pine and red pine forest managed using different silvicultural systems in ecoregions 3E and 4E from 1989 to 2005.[62]

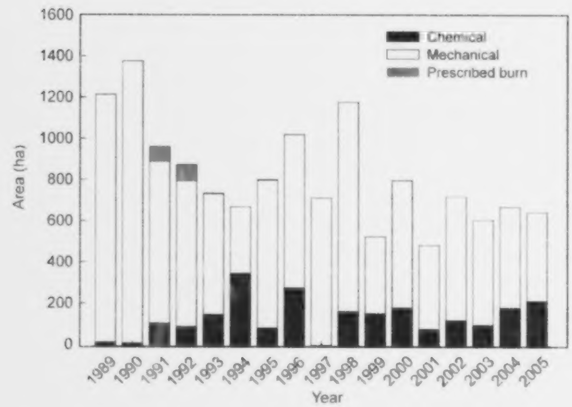

Figure 43. Area of white pine and red pine forest site prepared using different methods in ecoregions 3E and 4E from 1989 to 2005.[64]

system was applied to only 4% (~36 ha). This likely reflects the scarcity of stands with a high white pine component: most stands containing white pine in this ecoregion have insufficient (<12 m^2 ha^{-1}) white pine basal area to use shelterwoods.

The three primary silvicultural activities applied to secure and improve regeneration are site preparation, artificial regeneration, and stand tending to control competing vegetation. From 1989 to 2005, site preparation was applied to 14,130 ha of stands of the PRW forest type in ecoregions 3E and 4E, with 82% of the area treated with mechanical methods, 17% with chemical methods, and only rarely with prescribed burning (~1%) (Figure 43). Although prescribed burning emulates natural disturbance of white pine forests by low intensity wildfire, and may be applied either before or after harvest (Van Wagner and Methven 1978, McRae et al. 1994), it is seldom used operationally. Reasons for this include the cost of planning, the required liability insurance, the need for specialized expertise, and restrictive weather and stand condition requirements (McRae et al. 1994).[63]

In ecoregions 3E and 4E natural regeneration is rarely used as the sole method of reforestation. This may be due to difficulty in coordinating understory disturbance with the good seed years needed for adequate establishment of natural regeneration. This operational issue, coupled with the relatively slow

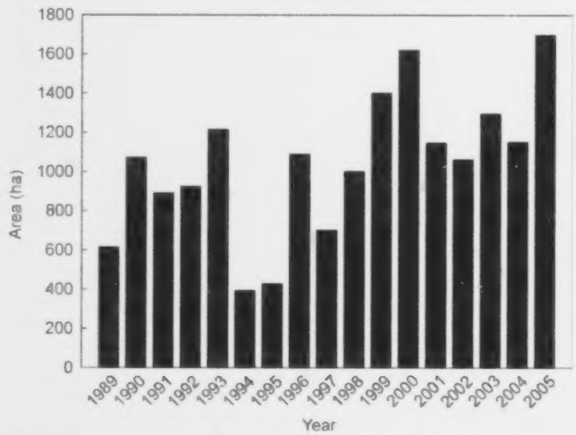

Figure 44. Area of white pine and red pine forest planted[65] *in ecoregions 3E and 4E from 1989 to 2005.*[66] *The relatively high area in 2005 is associated with above average planting efforts in the Algoma, Northshore, and Sudbury forest management units.*

initial growth of natural regeneration and higher level of silvicultural assistance required, may have contributed to reliance on artificial regeneration. The area planted in ecoregions 3E and 4E varies annually with almost 18,000 ha planted from 1989 to 2005 (Figure 44).

Stand tending or vegetation management to control competing vegetation is typically applied after regeneration is established to improve the growing environment and resource availability for desired

[62] Even-aged silvicultural systems (clearcut, shelterwood) were not classified separately in provincial forest statistics until 1996. Data from annual reports on forest management (Don Higgs, Programmer/Analyst, OMNR)

[63] Algoma Forest FMP (2005)

[64] Data from annual reports on forest management (Don Higgs, Programmer/Analyst, OMNR)

[65] Includes area planted in stands managed under both the clearcut and shelterwood silvicultural systems

[66] Data from annual reports on forest management (Don Higgs, Programmer/Analyst, OMNR)

trees. This may be accomplished through aerial or broadcast herbicide application or manual removal of competing vegetation, with a single treatment rarely being adequate to assure growth of pine regeneration to free-to-grow status. From 1989 to 2005, about 12,000 ha of PRW (across both ecoregions) received stand tending treatments to control competing vegetation, primarily (62%) using one of the registered herbicides (Figure 45). The use of stand tending as a silvicultural option for the PRW forest type is increasing. Manual (i.e., mechanical) methods to control competition were used on the remaining 38% of the area tended during this period. Tending methods are selected based on cost, the silvicultural system used for regeneration, and physiological and reproductive characteristics of the dominant plant species to be controlled.

Research and operational trials have yielded a variety of improved techniques for competition control for a range of conifer regeneration scenarios (Thompson and Pitt 2003). For example, aerial herbicide spraying was recently demonstrated to be a viable option to release white pine regeneration from deciduous tree competition in shelterwoods (Morneault et al. 2003). Alternatives to herbicides for stand tending of conifer regeneration are also available, but vary in cost and effectiveness relative to chemical control (Thompson and Pitt 2003). These options can involve different combinations of site preparation, regeneration and/or stand tending approaches. For example, a combination of heavy

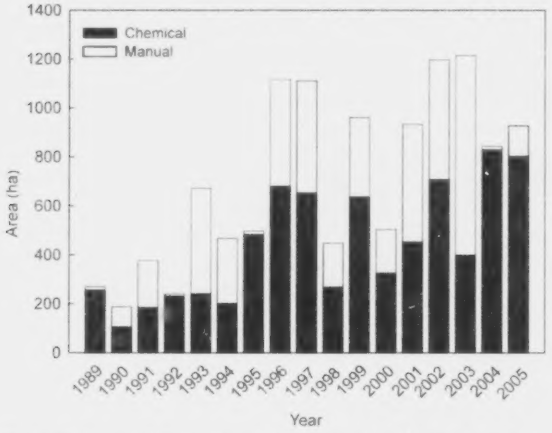

Figure 45. *Area treated using chemical and manual stand tending methods on land regenerated to white pine and red pine in ecoregions 3E and 4E from 1989 to 2005.*[67]

mechanical scarification and large, more competitive planting stock has been used to enhance regeneration where herbicides are not a viable option (Jobidon et al. 2003, Thiffault et al. 2003). Nutrient loading of nursery stock has also been shown to improve establishment success on competitive sites (Mallik and Timmer 1996, Imo and Timmer 2001). Biological control of resprouting by several competing deciduous woody species using *Chondrostereum purpureum* (Pers. Ex Fr.) Pouzar, a common native fungal pathogen, is also a promising stand tending option (Jobidon 1998, Pitt et al. 1999).

7.3.4 Monitoring

The MNR is legally obligated to monitor, assess, and report on forestry activities occurring on Crown land. As well, the MNR conducts or supports monitoring efforts to ensure SFL holders comply with MNR policy and legislation. The resulting information forms part of a sustainability assessment and is ultimately reported to the public via provincial annual reports on forest management,[68] five year state of the forest reports[69], and IFAs.[70] Monitoring and assessment are also critical to continued improvement of provincial guidelines and policies, and to follow up on operational testing of new science-based techniques. At the FMU and regional level, this information also provides a measure of the effectiveness of accepted forestry activities and is essential to the adaptive management cycle whereby practitioners learn from operational experience and continue to improve forest practices.

The MNR uses a variety of formal, structured monitoring procedures and programs to evaluate whether Crown forests are being managed sustainably. This monitoring may examine the effects of an activity on the environment (referred to as effects monitoring), the effectiveness of forest activities in achieving their objectives (referred to as effectiveness monitoring), or how well SFL holders have met their legal obligations and the objectives of their current FMP (referred to as compliance monitoring) (OMNR 2001b).

Silvicultural effectiveness monitoring

Application of forestry activities that maintain or increase the abundance of white pine on the landscape is fundamental to the objective of sustainable management of this species. The success or failure of silvicultural precriptions in achieving this objective is evaluated using a formal process of silvicultural effectiveness monitoring (SEM). Forest management plans include silvicultural ground rules that outline the suite and timing of practices to be applied to attain a desired future forest condition (stocking, target

[67] Data from annual reports on forest management (Don Higgs, Programmer/Analyst, OMNR)

[68] http://www.mnr.gov.on.ca/en/Business/Forests/Publication/MNR_E000163P.html

[69] http://www.mnr.gov.on.ca/en/Business/Forests/Publication/196959.html

[70] http://www.mnr.gov.on.ca/en/Business/Forests/2ColumnSubPage/STEL02_166359.html

species, acceptable species). Silvicultural effectiveness monitoring is primarily used to evaluate whether regeneration to the desired forest condition is occurring within a reasonable period of time (OMNR 2001b). The SEM manual establishes a basis for measuring, collecting, analyzing, and reporting information on the renewal of forests after harvest or disturbance (OMNR 2001b).

To determine whether SFL holders are meeting their regeneration objectives, they are required to conduct free-to-grow surveys. These surveys seek to quantify whether regeneration activities have created "stands that meet stocking, height, and/or height growth rates as specified in the silvicultural ground rules and are judged to be (healthy and) essentially free from competing vegetation" (OMNR 2001b). Assessment methods can be extensive (e.g., aerial survey) for areas where regeneration status can be visually determined. Accepted, more intensive methods are applied where regeneration status is uncertain or where quantitiative data is required (OMNR 2001b). These surveys provide the critical measure to determine regeneration success or failure. As well, they enable forest managers to assess how well their young forests are growing, and to identify areas that will require further treatment to reach the intended future condition.[71]

Annual reports on forest management prepared by SFL holders provide some indication of the overall effectiveness of recent white pine regeneration efforts in ecoregions 3E and 4E. Over the past 12 years, regeneration success of harvested PRW stands has ranged from 0% to 97%, with average regeneration success rate of 64% for the total area assessed during this period (Figure 46). Unfortunately, assessments prior to 2004 did not distinguish between PRW stands that successfully regenerated back to PRW and those that regenerated to other forest types. The latter stands would be considered a regeneration success since the stand did meet a regeneration standard of some forest type, but a silvicultural failure since the objective of regenerating to PRW was not achieved. Hence, the rate of successful regeneration to PRW prior to 2004 is difficult to quantify, and is likely iower than the values presented in Figure 46. The apparent improvement in regeneration of the PRW forest type in 2004-05 is due to the relatively high overall regeneration success for the Northshore, Spanish, and Nipissing FMUs.

Considering only regeneration assessment data reported for 2004 and 2005,[73] 38.9% (~342 of 879 ha) of the area previously classified as PRW forest type successfully regenerated to this same forest type (Figure 47). A significant portion of the remaining area regenerated to intolerant hardwood (23.9%) or mixedwoods (17.1%). This comparatively low silvicultural success is likely associated with difficulty in controlling competing vegetation, particularly in stands/

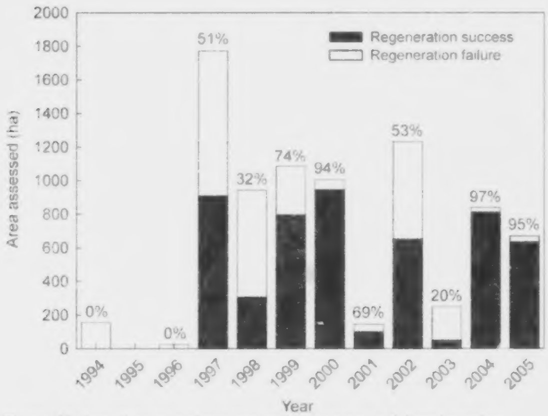

Figure 46. Area determined a regeneration success or failure based on regeneration assessments for the white pine and red pine (PRW) forest type in ecoregions 3E and 4E from 1994 to 2005. Numbers above the vertical bars refer to the percent of area assessed that was successfully regenerated for a given year. Regeneration assessments were not performed in 1995.[72]

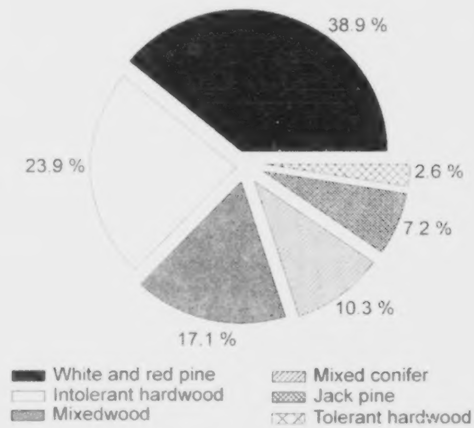

Figure 47. Proportion of provincial forest types regenerating after harvest of white pine and red pine (PRW)[73] stands in 2004 and 2005.[74] Data for ecoregions 3E and 4E are combined.

[71] A stand surveyed and deemed a failure in one year could be retreated and/or reassessed at a later date and judged to be a success.
[72] Data from annual reports on forest management (Don Higgs, Programmer/Analyst for OMNR)
[73] These estimates are derived from limited available data and should be interpreted only as indication of possible trends. Sampling efforts have also likely differed among provincial forest units or forest management units.
[74] Excluding pure red pine stands

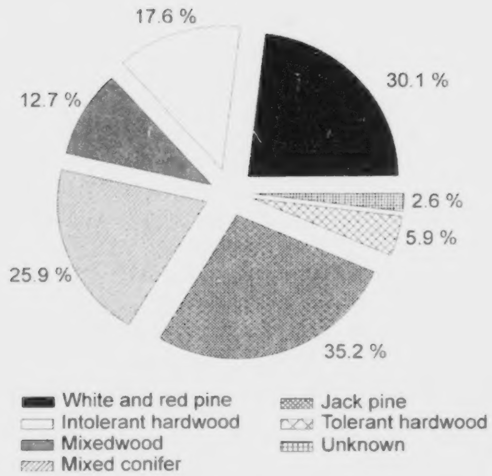

Figure 48. *Proportion of all provincial forest types successfully regenerated to white pine and red pine (PRW) in 2004 and 2005.*[76] *Data for ecoregions 3E and 4E are combined.*

FMUs with rich, fresh-to-moist soils (Wray 1985, OMNR 2004e).[75] However, in accordance with FMP objectives of some FMUs for white and red pine restoration, an additional 1107 ha or 30.1% of other forest types was harvested and successfully converted to PRW (Figure 48). These restoration efforts contributed ~70% of the total area successfully regenerated to PRW forests. More than 60% of the 1,450 ha of this PRW regeneration was derived from harvest and silvicultural conversion of the mixed conifer and jack pine provincial forest types.Greater attention to establishment of natural and artificial regeneration and timely, site-specific application of competition control treatment is needed to further increase the area regenerated to PRW (OMNR 1998a, Thompson and Pitt 2003, Wagner et al. 2006).

Independent forest audits

The CFSA requires that MNR use a system of IFAs to measure the progress of SFLs towards the achievement of goals, objectives, targets, and desired planning outcomes stated in the approved FMPs as well as to monitor compliance with provincial forest management legislation, policies, and guides. Audits of each FMU are conducted every five years by a third party independent of the SFL and the MNR. To address any identified short-comings, action plans are developed jointly by the SFL and the MNR. For example, strategies for managing white and red pine were implemented by some SFLs following recommendations by auditors.[77] Future IFAs will examine the results of the corrective actions implemented.

7.3.5 Research

The birth of scientific forestry in North America at the turn of the 20th century initiated a great deal of forest research activity directed at understanding white pine ecology, physiology, and pathology to improve silviculture and management (Horton and Bedell 1960, Wilson and Hough 1966, Wendel and Smith 1990, Kershaw 1993b). Probably because of its early economic importance to Canada and the United States, white pine was the first North American tree species to undergo a thorough examination of its silvics and management (Pinchot and Graves 1896, Frothingham 1914). The degree of attention given to this species from 1890 to 1954 is demonstrated in the white pine bibliography of Wilson and Hough (1966) that includes references to almost 950 research and other reports. White pine research has also received considerable attention in Canada and Ontario since 1918, when Canada's first forest field trials were established at the Petawawa Research Forest (Horton and Bedell 1960, Stiell 1994, Place 2002, Burgess and Wetzel 2002, Bevilacqua et al. 2005). Because of its comparatively high productivity and value relative to other conifers, white pine has been the subject of numerous scientific monographs (e.g., Horton and Bedell 1960) and symposia (e.g., Cameron 1978) and continues to be a species of research interest by the MNR, the Canadian Forest Service, universities, and forest industry.

Although much of the knowledge of white pine is generally applicable to Ontario, several forest management issues specific to the Northeast Region require additional science-based information. The relatively small, scattered, and isolated nature of many of the white pine stands in the northernmost portion of its climatic range, particularly in Ecoregion 3E, will require further development and refinement of silvicultural approaches to regenerate this species and conserve its genetic diversity (Buchert 1994, Daoust and Beaulieu 2004). Restoring this species will depend on more knowledge of plantation establishment and tools to reduce the incidence of blister rust, given that both ecoregions 3E and 4E are rated as severe blister rust hazard zones.

[75] The primary objective of every FMP examined was to regenerate PRW forest units back to this same forest type, and only occasionally when the site was not suitable for white pine, to some other forest type.

[76] Excluding pure red pine stands

[77] Sudbury Forest IFA (2001), Superior Forest IFA (2002), Sudbury Forest IFA (2005), and Martell Forest IFA (2006)

The MNR and its partners are currently involved in several research projects focussed primarily at ensuring the regeneration and establishment of white pine.[78] Of particular importance to restoration efforts in the Northeast Region is forest genetics research directed at identification and development of naturally rust resistant varieties of white pine, and interspecifc hybrids of white pine with rust resistant Eurasian pine species (e.g., *Pinus wallichiana* A.B. Jackson) (Daoust and Beaulieu 2004, Lu et al. 2005). Blister rust resistant hybrids are currently the most promising sources of planting stock for use in relatively high hazard zones. Other white pine research projects are investigating: (1) vegetation management methods appropriate to artificial regeneration in shelterwoods and plantations, (2) production of improved seed for nursery seedling production for planting, (3) silvicultural effectiveness of recent regeneration practices, and (4) various combinations of partial cutting, underplanting, site preparation, and competition control. Researchers and technology transfer specialists are actively using field demonstration areas, workshops, written reports, and other media to communicate this information to forest managers to assist in its operational application. This new knowledge will also be incorporated into the provincial silviculture guides during their next revision.

[78] White pine management studies: http://www.mnr.gov.on.ca/en/Business/OFRI/2ColumnSubPage/STEL02_165652.html; White pine blister rust studies: http://www.mnr.gov.on.ca/en/Business/OFRI/2ColumnSubPage/STEL02_165654.html

8 Challenges to the management of white pine forest resources

8.1 Economics of white pine silviculture

Currently, the primary challenge to sustainable management of white pine in ecoregions 3E and 4E, and the province in general, seems to be the relatively high economic cost associated with the comparatively intensive silvicultural treatments often required for its regeneration.[79] Silviculture can be defined as the art and science of regenerating, tending, and maintaining a forest to best fulfill the objectives of the landowner. The investment in silviculture is weighed against the potential economic return on this investment. As discussed previously (Section 4.2.1), the value of white and red pine can be high relative to that of other conifers, particularly for large, high quality stems. Since cost per unit of harvested wood volume decreases as average tree size increases, harvesting costs are also generally lower for species such as white pine. Reduced harvesting costs coupled with the value and market demand for larger, quality white pine should provide an additional incentive for investment in more intensive white pine management.

Currently and in the past, the poor market for smaller, lower quality white pine being harvested reduced investment in pine silviculture.[80] For example, some SFL holders are reluctant to "thin from below" during the regeneration cut of the shelterwood system (i.e., the recommended preferential harvest of suppressed white pine and other species). This practice creates an optimal understory light environment for pine regeneration, but is costly in the short-term when this smaller diameter material provides no financial return. Increased use of forest biomass as an energy source in Ontario may provide the economic impetus for future removal of this material.

Silvicultural investment in white pine management also depends on the perceived probability of desired outcomes from operational application of recommended approaches and tools. For example, some forest managers are reluctant to invest in white pine silviculture due to uncertainty as to whether partial harvesting systems will secure consistent, successful regeneration. Continued development and demonstration of silvicultural methods with an acceptable probability of success are needed to increase forest manager confidence in their operational use.

8.2 Fire suppression

In northern Ontario, institutional fire suppression has resulted in harvest replacing natural wildfire as the primary forest disturbance agent (Carleton 2000). Harvest and associated management practices have much different effects on post-disturbance forest environment, structure, function, forest-insect interactions, and succession than wildfire (Carleton and MacLellan 1994, McCullough et al. 1998, Carleton 2000, McRae et al. 2001). Despite debate as to the influence of fire management on the annual area burned and fire cycle in the boreal forest of Ontario (Ward et al. 2001, Bridge et al. 2005, Martell and Sun 2008), suppression has nearly eliminated the incidence of slow-spreading, low intensity surface fires from the landscape (Van Sleeuwen 2006). This is one of several factors that has contributed to the reduced regeneration of white pine forests, and threatens to further reduce their abundance on the landscape in the future (Maissurow 1935, Day and Carter 1991, Frelich 2002, Weyenberg et al. 2004). As a result, silvicultural treatments that recreate the effects of fire on stand structure, understory microenvironment, and forest floor conditions are essential to securing successful natural and artificial regeneration after logging, particularly on more productive, competitive sites. The MNR's new balanced approach to fire management (see Section 7.1.2), recognizing the positive effects of fire to regenerate fire-adapted species could improve regeneration of white pine, especially in protected areas (OMNR 2004a,b).

8.3 Competing vegetation

Although the amount and form (herbaceous, woody) of competition differs among reforestation sites, early control of competing vegetation has consistently been shown to have positive, long lasting effects on the growth of conifer regeneration, including white pine (Wagner et al. 1999, 2006; Thompson and Pitt 2003). Appropriate timing and duration of herbaceous and woody vegetation control is also crucial to optimizing conifer growth (Wagner et al. 1999, 2006; Thompson and Pitt 2003, Pitt et al. in press). Despite advancements in methods and tools available for forest vegetation management for conifers, a reluctance[81] or inability (due to a lack of funding) by some to conduct early stand tending operations still exists in Ontario. This usually results in inadequate competition control

[79] Temagami Forest FMP (2004)

[80] Superior Forest IFA (2003), Spanish Forest IFA (2005)

[81] Algoma Forest FMP (2006)

being a common cause of white pine regeneration failure. In part, this is a by product of a lack of information about when and how to apply tending as opposed to a shortage of operational tools (Wagner et al. 1999, 2006; Thompson and Pitt 2003). Economic considerations aside, a fundamental difference of opinion is evident among practitioners in Ontario as to when stand tending of white pine regeneration is needed and most effective. Recent emphasis on technology transfer related to the need for early vegetation management in white pine clearcuts and shelterwoods is beginning to alter these perceptions and increase confidence in operational use of available, recommended methods.

8.4 Genetics and seed production of small white pine populations

Harvest of the relatively small, scattered white pine stands of Ecoregion 3E requires special consideration of genetic resources management. Past research indicates that partial harvest may not adversely affect genetic diversity of white pine stands provided they are not isolated and have large residual breeding populations (Beaulieu and Simon 1994, Buchert et al. 1997, Anderson et al. 2002, Marquhardt et al. 2007). Regardless of harvesting practices, small and marginal white pine forests with few, scattered and widely spaced white pine trees may be predisposed to non-random mating, inbreeding, production of self-fertilized, empty seed (Rajora et al. 2002, Major et al. 2008), and loss of genetic diversity (Buchert 1994). Inbreeding can reduce the probability of successful regeneration of white pine and other forest tree species (Johnson 1945, Buchert 1994, Ledig 1998, Major et al. 2008). In northern areas where the white pine resource was small to begin with and/or has been reduced and fragmented, the genetic diversity of seed trees may already have been eroded by past "high-grading" of the largest, best quality trees (Daoust and Beaulieu 2004, Pinto et al. 2008).

The collection of large amounts of quality seed is needed to support nursery production of planting stock that is genetically adapted to MNR's climatically based seed zones (see Section 7.1.3). While the infrequent, above average seed crops of white pine are an impediment to seed collection across the province, an additional challenge to efforts to artificially regenerate white pine in Ecoregion 3E is the relatively small number of stands available for seed collection. The higher probability of inbreeding and formation of empty seed in smaller stands may reduce regeneration potential (Rajora et al. 2002, Major et al. 2008), but the prevalence of this problem in Ontario is unknown.[82]

[82] Romeo Malette Forest FMP (2006)

8.5 White pine weevil and blister rust

Controlling damage by white pine weevil and blister rust is a significant challenge to white pine management in ecoregions 3E and 4E. This is the result of northeastern Ontario's favourable climate for very high rates of blister rust infection coupled with the regional need for white pine restoration. Guidelines have been developed to assist forest managers in selecting silvicultural techniques to control these two pathogens (Katovich and Mielke 1993, OMNR 1998a, deGroot et al. 2005). Unfortunately, despite advancements from decades of effort to identify and develop blister rust resistant genotypes and interspecific hybrids, improved pest resistant nursery stock is not yet available for planting (Daoust and Beaulieu 2004, Kriebel 2004). Although registered pesticides may be effective, they are unpopular with the public, and silvicultural approaches are preferred over chemical control of insects and diseases on Crown forests (OMNR 1998a).

Currently, the most effective operational option to reduce damage from weevil and blister rust is an integrated approach using: (1) silvicultural practices to create and maintain unsuitable microenvironmental conditions for these organisms, and (2) corrective and pathological pruning (MacAloney 1930, Katovich and Mielke 1993, deGroot et al. 2005). The best approach to minimize damage by weevil and blister rust is to manage young pine beneath an existing overstory canopy. When restoration using plantations is the objective, careful site selection to avoid topographic and stand features associated with high likelihood of rust infection is critical. Repeated pruning of the lower branches to minimize mortality by blister rust and corrective pruning of pine damaged by weevil will also be required when regeneration is via plantations.

8.6 Climate change

Climate change is anticipated to influence the structure, composition, function, and management of Ontario's forest ecosystems via effects of elevated atmospheric CO_2 concentration, increased temperature and (perhaps) drought, and more frequent disturbance and extreme climatic events (Parker et al. 2000). This will affect all forest species and regions of Ontario, with species occupying small, disjunct populations perhaps being more vulnerable to these changes. An increased future frequency of stand-replacing fire in 3E could result in total destruction of the few, small, and scattered white pine stands, dramatically reducing their abundance on the landscape. Increased fire also poses

a significant threat to the old growth white pine stands in ecoregions 3E and 4E.

White pine was most prevalent and widely distributed in North America during a post-glacial period 4,000 to 9,000 years ago with a warmer, drier than present climate, when it dominated sites with till and outwash soils of fine to intermediate texture (Jacobson 1979, Liu 1990, Jacobson and Diffenbacher-Krall 1995). The cooler, wetter climate period that followed is thought to have improved moisture conditions on these sites sufficiently to shift the competitive advantage from white pine to more mesophytic forest tree species (e.g., birch, maple, hemlock), reducing the abundance of white pine (Brubaker 1975, Jacobson 1979). The moister climate and increasingly deciduous species composition may also have reduced the fire frequency, further contributing to the succession from white pine to hardwood-dominated forests (Swain 1973, Jacobson and Dieffenbacher-Krall 1995). Therefore, where the future climate is warmer and drier than at present, white pine may increase in abundance due to its greater drought tolerance than associated hardwood species.

White pine is a predominantly outcrossing species with relatively high genetic variability (Daoust and Beaulieu 2004). Range-wide provenance testing in the eastern United States and within Ontario indicate broad genetic variation among populations in growth, cold hardiness, shoot phenology, and other traits (Buchert 1994, Joyce et al. 2002, Lu et al. 2003a,b, Kriebel 2004). Some white pine stands in Ecoregion 3E may be relict populations of the warmer, drier post-glaciation period, and genetically adapted to warmer climates. This inherent genetic diversity and moderate to high heritability of certain traits of white pine suggest that tree improvement programs to develop white pine varieties with improved growth potential or adaptation to climatic stresses are possible (Daoust and Beaulieu 2004). Increased knowledge of genetic variation among white pine populations in Ontario and adjacent areas will increase our capacity to adapt white pine forests to climate change. This information would be useful to guide seed transfer for reforestation and to begin breeding programs directed at nursery production of climatically adapted planting stock (Parker et al. 2000).

9 Forecast for the Future

Following the directions of the CFSA and FMPM (OMNR 2004c) for sustainable forest management of Ontario's Crown forests, the SFMM (Davis 1999) is used to forecast future amounts (i.e., area and volume) of different forest types that result from active forest management (i.e., wildfire suppression[83] and harvest as the primary disturbance agent). Licensees are required to develop various forest management alternatives and estimate the effect of these scenarios on future forest area and wood supply. The approach deemed most suitable to the achievement of management objectives, referred to as the selected management alternative (SMA), is compared to future forest conditions that would form under a natural benchmarking (NB) scenario if no management were applied (i.e., no harvest, no fire suppression, and wildfire[84] as the dominant disturbance agent). These simulations also permit changes in area of managed forests in FMUs to be separated from those of protected areas (i.e., provincial parks and conservation reserves). The SFMM simulations for PRW forests contained in current approved FMPs of SFLs in ecoregions 3E and 4E are used here to provide a general projection of changes: in future total area of the PRW forest type, area of PRW old growth, and white pine wood supply that can be achieved if the SMA were applied on these SFLs for the next 100 years.[85]

9.1 Area of white pine and red pine forest type

Under the SMA scenario these SFMM simulations project an increase of more than 200% in the total area of PRW forests on actively managed FMU lands in Ecoregion 3E and about 46% in Ecoregion 4E (Figure 49a,c). Relatively little response to SMA is apparent in the smaller area of PRW forests in protected areas,

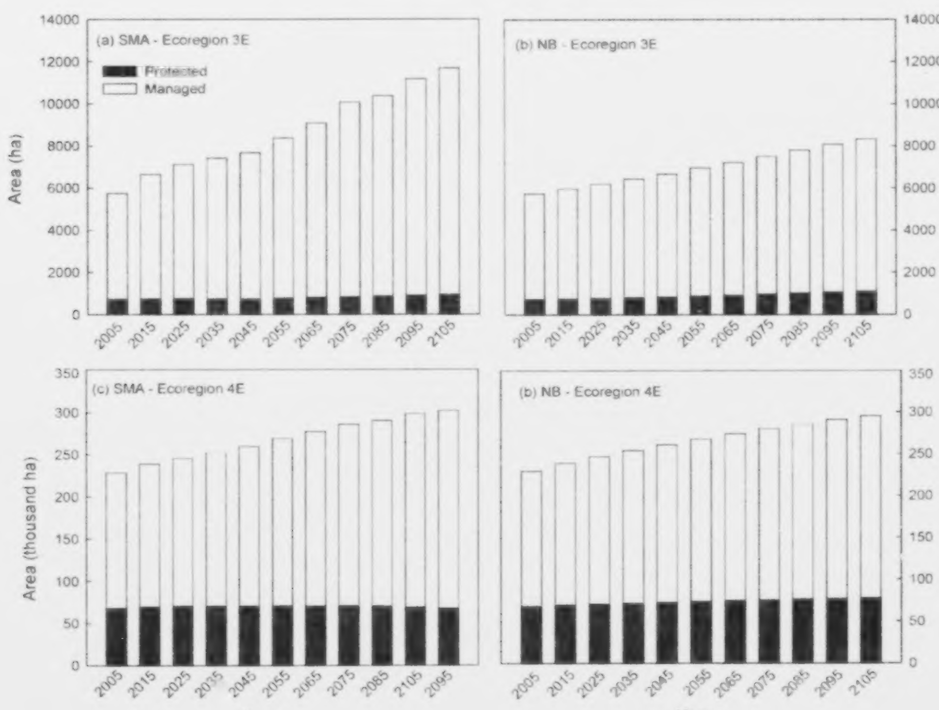

Figure 49. Forecast change in area of PRW stands on protected and managed land within forest management units under the selected management alternative (SMA) (a,c) and natural benchmarking (NB) scenario (b,d) for ecoregions 3E (a,b) and 4E (c,d).

[83] A percentage of the managed area is assumed to burn despite suppression efforts and differs among SFLs.

[84] A specific wildfire regime is assumed for the NB scenario and differs among SFLs.

[85] The SFMM results in Section 10 were provided by Michael Malek, Resource Analyst, Northeast Regional Planning Unit, OMNR.

with a 30% increase in Ecoregion 3E and no change in Ecoregion 4E (Figure 49a,c).[86] The relatively constant or slightly increased area of PRW forests predicted for protected areas at the ecoregional level is counter to findings that unmanaged white and red pine forests often naturally succeed to other forest types in the absence of fire disturbance (Day and Carter 1991, McRae et al. 1994, Carleton et al. 1996). At the FMU scale, however, both decreases and increases in area of PRW forests in protected areas are projected for individual FMPs. Where the area of PRW in protected areas increases over time, it results from succession[87] of the spruce-fir to the PRW forest unit in existing parks and reserves, coupled with an increase in the area of PRW protected reserves around areas of concern (e.g., buffers around water bodies and raptor nests) (Mike Malek, OMNR, pers. comm., 2008).

The SFMM simulations indicate that active forest management (i.e., SMA) has significant potential to increase the total area of PRW on FMUs, particularly in Ecoregion 3E,[88] relative to that projected for the NB scenario. Despite the forecast increase of 0.06 to 0.11% and 8.49 to 9.28% of the total land area, respectively, occupied by PRW in ecoregions 3E and 4E, this is still less than half that estimated to exist prior to settlement (Table 3) (Pinto et al. 2008). This projected increase in area of PRW under SMA scenarios is expected to support higher harvest levels on actively managed forests (FMUs) (Figure 50). In both ecoregions, the area (of managed and protected forests) disturbed by fire under the NB scenario is expected to increase with time but fall below the area harvested under the SMA scenario.

9.2 Area of old growth white pine and red pine forest type

A key feature of MNR's current old growth policy is the objective of balancing conservation and sustainable harvest to provide for functional old growth forests over time on managed Crown forests (OMNR 2003a). The SFMM simulations of the SMA scenario suggest that maintaining the area of old growth white pine forests in FMUs will be comparatively challenging over the long term, particularly for Ecoregion 3E. The SMA scenario projects a short-term (10-year) increase in the area of old growth PRW stands in Ecoregion 3E followed by a marked decrease over the remainder of the simulation period (Figure 51a). Over this timeframe, the area of old growth is forecast to decrease by about 60% on managed forests and increase by about 50% in protected areas, for a total (area-based) reduction of 42% in Ecoregion 3E. By comparison, active management is projected to increase the area of old growth PRW stands in Ecoregion 4E for the next 50 years, followed by decreases (Figure 51c). More specifically, over the simulation time frame, old growth PRW is expected to increase by about 35%

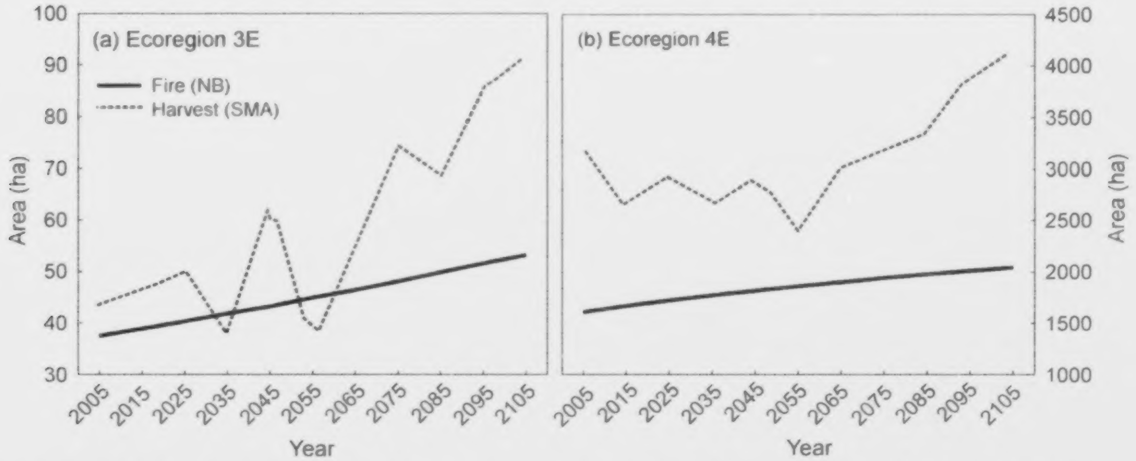

Figure 50. *Area of PRW stands forecast for harvest under the selected management alternative (SMA) scenario compared to the area disturbed by fire under the natural benchmarking (NB) scenario for ecoregions 3E (a) and 4E (b). Area burned includes both managed and protected forests.*

[86] Throughout this section, relative change in area due to SMA and NB scenarios is estimated as the percent change in total area in 2005 compared to projected total for 2105.

[87] Succession rules used in the forecasting exercise in SFMM differ among FMPs.

[88] Algoma Forest FMP (2005), Pineland Forest FMP (2006)

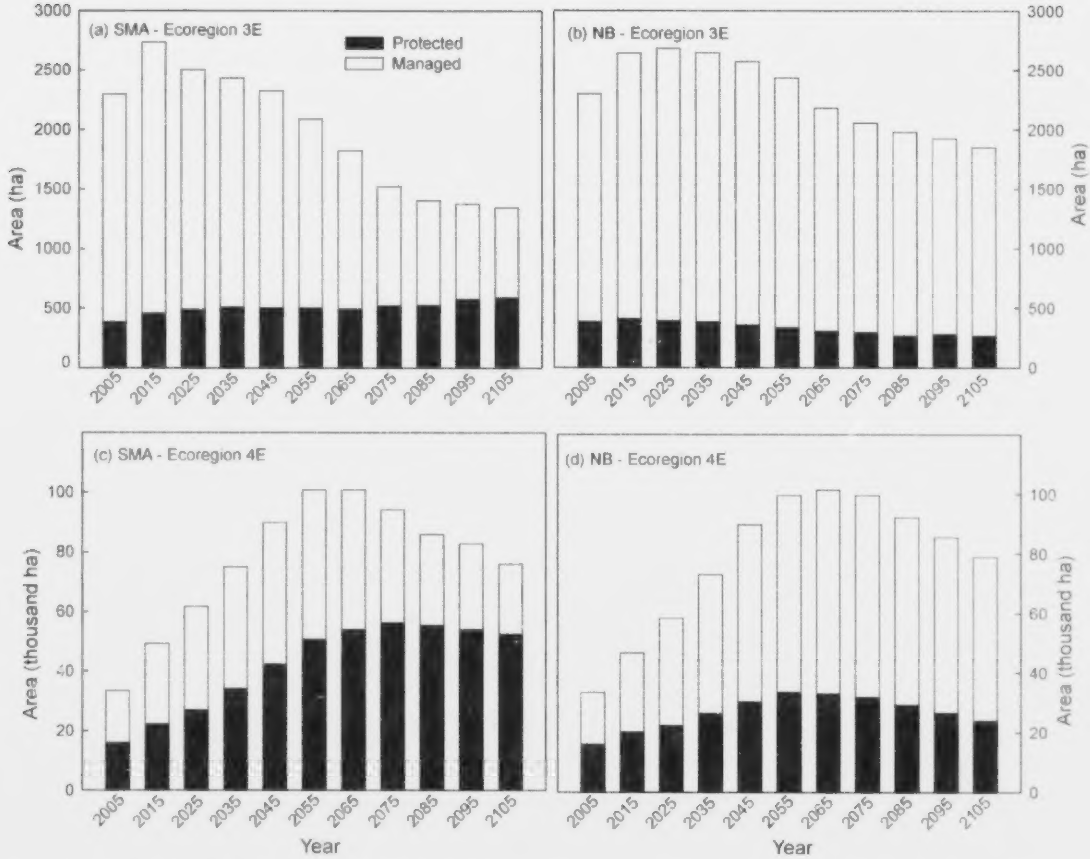

***Figure 51.** Forecast change in area of old growth PRW stands on protected and managed land within forest management units under the selected management alternative (SMA) (a,c) and natural benchmarking (NB) scenario (b,d) for ecoregions 3E (a,b) and 4E (c,d).*

and more than 300% in managed and protected areas, respectively, with the total area of old growth PRW more than doubling over this period. Similar temporal patterns in area of old growth PRW are forecast under the NB scenario (Figure 51b,d), with a smaller net decrease in area forecast for Ecoregion 3E than projected under the SMA scenario.

The model projections for the SMA scenario are somewhat optimistic because they include older PRW stands being managed using the shelterwood silviculture system until the final removal harvest occurs.[89] While tree marking is used to maintain old growth characteristics in these stands when they are <130 years old, they probably lack the complete structure and ecological function of true old growth forests (Bebber et al. 2005). That said, some of the old growth PRW currently protected may also be dissimilar to that existing prior to settlement due to past selection harvesting, decades of fire suppression and, in some instances, their small size.

Several factors are responsible for the reduction in projected area of old growth PRW under the SMA scenario. The inflection points observed in the simulations presented in Figure 51 identify the decade when losses (i.e., outflows) of old growth PRW stands begin to exceed areas of new old growth (i.e., inflows). Inflows are primarily due to the growth of younger cohorts (as determined by the current PRW age structure) to older seral stages, and succession of

[89] The Old Growth Policy for Ontario's Crown Forests "does not provide direction on whether old growth stands managed under the shelterwood system can contribute towards achievement of the old growth" targets (OMNR 2007a).

other forest types (lowland hardwoods (LH1), tolerant hardwoods (TH1), and successional mixedwoods (MW2)) to PRW (Vasiliauskas et al. 2004). The current age class structure of PRW forests influences ongoing efforts to manage Crown forests for old growth (see Section 5.2.2). The relatively few existing stands less than 80 years old will result in comparatively little area available for potential old growth forests (i.e., >130-150 years) 50 to 70 years from now. The downward trend in old growth area about 50 years from now (Figure 51) is, in part, a reflection of the comparatively small inflow from these younger age classes. Forest managers have few options to address this factor as it affects future old growth. In the longer term, application of management practices to improve white pine and red pine regeneration will obviously increase the area of younger PRW stands on the landscape and enhance the potential to increase the area of PRW old growth.

Outflows of old growth occur due to successional replacement of PRW by other forest types and harvesting of PRW. As much as 40% of the white pine (PW1) and PRW forest units may succeed to the mixedwood (MW2) or spruce-fir (SF1) forest units at 170 to 250 years of age (Vasiliauskas et al. 2004).[90] Severe windstorms can accelerate this succession due to the vulnerability of larger, older pine to blowdown (Foster 1988, Tester et al. 1997). Stands with higher stocking of large advanced regeneration of pine will be less likely to undergo natural succession to these forest types composed of more shade tolerant species. Therefore, forest managers can reduce the area subject to successional displacement of PRW through timely silvicultural intervention to encourage pine regeneration. For example, use of prescribed burning or allowing some natural wildfires to burn may decrease the amount of shade-tolerant species in the understory and maintain old growth PRW stands (McRae et al. 1994, Tester et al. 1997, Beverly and Martell 2003).

Harvest represents a larger source of outflow than does natural succession in these SFMM simulations (Figure 52). Increased harvest levels projected for Ecoregion 3E represent 79% of the total outflow of PRW, on average, over the 100-year simulation period. An average of 60% of the projected area harvested is PRW stands classified as old growth. By comparison, loss of old growth PRW to natural succession is projected to average 21% of the total outflow over this period. In Ecoregion 4E, harvest averages 93% and natural succession about 7% of the total outflow of old growth PRW. Of the area harvested, an average of 34% is projected to be old growth PRW.

The area of old growth PRW in provincial parks and conservation reserves is projected to increase by 53% in Ecoregion 3E and by more than 300% in Ecoregion 4E under the SMA scenario (Figure 51a,c). By comparison, the NB scenario is forecast to decrease old growth PRW by 31% in Ecoregion 3E, but increase by 50% in Ecoregion 4E (Figure 51b,d). Lack of fire suppression under the NB scenario is the primary factor that results in a greater loss of old growth PRW in protected areas than does the SMA scenario.

Overall, these SFMM simulations predict that current management practices (as defined by the SMA scenario) will, in the long run, decrease the area of old growth PRW stands on actively managed Crown forests, but increase their abundance in protected areas relative to the NB scenario. Greater operational application of current and future research results, periodic revision of the MNR silvicultural guides, and use of adaptive management to improve white pine management has the potential to increase the amount of future old growth PRW relative to that projected by the SMA scenario in current FMPs.

9.3 Wood supply

Over the past 10 years, demand for white pine and red pine in the Northeast Region has averaged about 175,000 $m^3 yr^{-1}$, roughly 25% more than the 135,000 m^3 being harvested annually (Figure 53). This shortfall in supply is due to a lack of quality sawlogs in the region, and a surplus of pulp grade pine with a limited market (OMNR 1998a, OMNR 2004e). In Ecoregion 3E, this shortage of larger, high quality logs can be attributed to past high grading practices, guidelines that protect the rare, remaining white and red pine stands in this area, and the high percentage of defective logs naturally produced at the northern limit of white pine's range.[91] In both ecoregions, lower availability of this economically desirable fibre is likely due to past inattention to pine regeneration and a historical reluctance to invest in more intensive silvicultural practices (e.g., thinning, pruning) that can improve lumber quality and log size (Section 7.1.3).

In the longer term, shortages in white pine wood supply are projected throughout the GLSL forest region because white pine forests are increasingly being managed for non-timber purposes (OMNR 2004e). In the near term (over the next 20 years), a decline in white pine supply is anticipated due in part to delayed harvest of older shelterwoods scheduled for a final removal cut (OMNR 2004e). Many of these stands have not successfully regenerated naturally and cannot be

[90] Succession data for PW1, PRW, and PR1 are scarce and these numbers are based on expert opinion only (Dave Etheridge, OMNR, pers. comm., 2008).

[91] Algoma Forest FMP (2005)

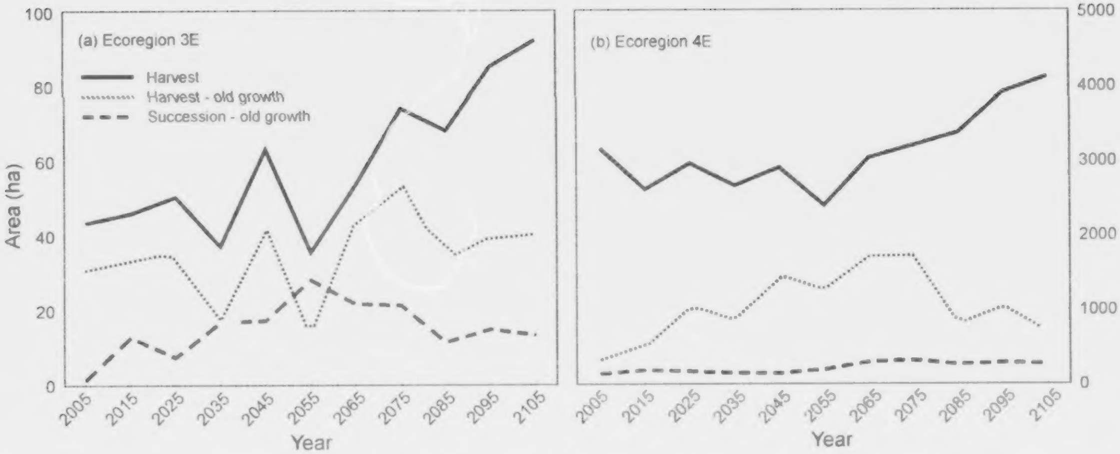

Figure 52. *Forecast change in area of PRW (mature and old growth) harvested, old growth PRW harvested, and old growth PRW that undergoes succession to other forest types in actively managed Crown forests in ecoregions 3E (a) and 4E (b).*

harvested until regeneration standards are met (OMNR 2004e). The MNR has proposed silvicultural efforts be directed to regenerate these areas. Greater emphasis on artificial regeneration and vegetation management by SFLs currently using shelterwoods is encouraged to minimize this source of future shortfalls in wood supply (OMNR 2004e).

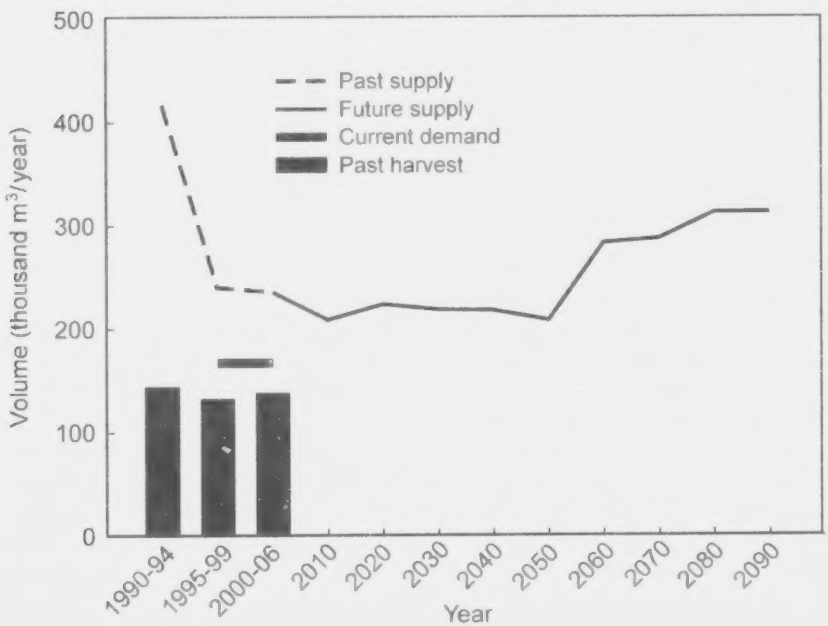

Figure 53. *Past and projected future supply of white and red pine in ecoregions 3E and 4E compared to past harvest levels and current mill demand. (Adapted from OMNR 2004c).*

10 Summary

White pine dominated forests covered a large area of eastern Canada at the time of European settlement. Ontario was blessed with perhaps the largest, most productive of these forests, with the white pine resource playing a significant role in the early economic development of the province. As the white and red pine forests silently served the needs of the early inhabitants, first for square timber followed by sawn lumber, few voiced concerns over the rapid rate at which these grand forests were being logged and the little thought given to their protection, renewal, or management. The introduction of white pine blister rust and fire suppression early in the 20th century further hampered the regeneration of white pine forests. At the same time, the importance of conservation and management of white pine forests, and forests in general, was being increasingly recognized. Maturation of the forestry profession in Canada, coupled with the initiation of publicly funded forest research, greatly improved our knowledge of the management, ecology, and myriad values of white pine forests. Unfortunately, this knowledge and growing appreciation of the values of white pine forests only slowly translated into improved operational practices, and loss of this species from the landscape continued. In northeastern Ontario, the area of white and red pine forests has decreased by 84 and 59% in ecoregions 3E and 4E, respectively, since the time of settlement.

Today, the value of white pine to the people of Ontario is widely recognized. Management of white pine for timber production remains vitally important to many northern communities. Few North American tree species are as productive, capable of inhabiting as wide a range of sites, and possess such desirable wood properties as white pine. The wood derived from large, higher quality white pine logs is consistently in demand and commands a relatively high market price, while its physical properties are well suited to a diverse array of value added forest products. At the same time, appreciation of the ecological and recreational values of white pine forests continues to grow and is increasingly reflected in forest policy regarding their management.

The relatively specific ecological requirements for white pine regeneration present a significant challenge to those charged with its management. Its intermediate shade tolerance, inherently slow initial growth rate, infrequent seed crops, susceptibility to blister rust and the weevil, and natural dependence on a complex wildfire disturbance regime, make white pine difficult to regenerate without comparatively intensive silvicultural intervention. The scattered distribution and small size of white pine forests near the northern limit of white pine's natural range, introduce additional challenges to its management.

With the advent of the CFSA in 1994, forest management in the province has undergone a fundamental shift. White pine forests are now managed for timber and non-timber values alike, and a comprehensive policy framework exists to address issues surrounding forest management planning, and the protection and conservation of ecological functions, biodiversity, and old growth forests. Knowledge gained from more than a century of forest research directed at understanding the ecology, regeneration, and management of white pine forests has been incorporated into a series of guides to assist forest managers. Current management of white pine in ecoregions 3E and 4E now relies on even-aged silvicultural systems that retain a portion of the overstory to better emulate natural disturbance patterns. This conserves a portion of the structural and biological legacy of the forest such as large, old healthy and standing and fallen dead trees. Where white pine trees and stands are rare on the landscape, guidelines have increased their level of protection. As a consequence, white pine harvest levels have decreased over the last decade in Ecoregion 3E but have remained relatively stable in Ecoregion 4E. White pine regeneration is commonly secured through planting with site-specific site preparation and stand tending to promote seedling establishment, growth, and survival. Comparatively little investment has traditionally been made in intensive management practices after the stand establishment phase, although the potential economic benefits of these practices have been demonstrated.

The age class structure of white and red pine forests in ecoregions 3E and 4E is imbalanced and heavily skewed towards older forests, the result of past harvesting exceeding the area successfully regenerated. The relative abundance of white pine stands <20 years old in Ecoregion 3E is encouraging and suggests that management practices needed to achieve acceptable white pine regeneration are available. However, the comparatively low percentage of younger age classes in both ecoregions is a significant impediment to SFL's current efforts to increase the area of PRW forests and future white pine wood supply. Despite scientific and technogical advancements in white pine management, monitoring

efforts over the past decade indicate regeneration success for PRW stands averaged only 64%. Clearly, further improvement in pine regeneration is needed.

Simulations using the SFMM derived from current, approved FMPs within ecoregions 3E and 4E project that selected management scenarios of SFLs will increase the area of PRW stands on the landscape to levels less than half of pre-settlement values. Greater silvicultural investment will likely be required to further increase pine regeneration and future wood supply and meet white pine management objectives identified in FMPs. These investments are critical to developing and maintaining a dynamic white pine forest industry in Ontario's northern communities. The area of old growth PRW forests is forecast to increase in the short term and then decline due to the current age class imbalance, harvest, and natural succession to other forest types. Disturbance by harvests and subsequent silvicultural treatments are needed in some old growth PRW stands to assure their maintenance on the landscape.

Many significant challenges to the management and restoration of white pine in these ecoregions still remain. Of particular importance is development, testing, and application of operationally feasible, economically attractive tools and approaches for: (1) increasing the establishment, survival, and growth rate of white pine regeneration, (2) management of small, isolated white pine stands to secure regeneration while conserving genetic diversity, and (3) reducing damage by blister rust and weevil in white pine plantations. The capacity of our white pine forests to recover from past mismanagement and to provide economic, social, and ecological benefits to future generations of Ontario will only occur with a continued commitment to sustainable management, protection, restoration, and rehabilitation of this species on the landscape.

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Appendix 1. Partial list of companies that were harvesting white pine in MNR's Northeast Region during late 19th and early 20th century.

Period of operation, total volume harvested, and land area of operation are provided when known. Information collected from Sudbury Lands and Forest District (undated), ODLF (1964c, 1965, 1967), Crossen (1976), Timiskaming Forest FMP (2006), and Northshore Forest FMP (2005).

Sawmill	Operating period	Volume harvested (m^3)	Area of operation
Hale & Booth	1877-1880	N/A	Shedden, Deagle, and Gaiashk Twps.
Chew Bros.	1885-	N/A	Wells and Day Twps.
N & E Dyment	1885-1910	N/A	Kirkwood, Bridgeland, Rose, and Haughton Twps.
Crook Bros. Co	1887-1905	N/A	Lockeyer, Gunterman, Bouck, Bolger, and Beange Twps.
Sage & Emery	1890-	25,938	Spragge and Esten Twps.
JJ. McFadden Lumber Co.	1891-1925	N/A	Jarvis, Gillmor, Nicholas, Kamichisitit, Varley, Jackson, Casson Sagard, Tweedle, Poulin, Thorp, Sayer, Le Caron, Nahwegezhic, and Duncan Twps.
	1901-1902	13,556	Dowling Twp.
	1927-1930	53,045	Venturi Twp.
	1936-1939	9,432	Secord Twp.
	1941-1943	4,716	Tofflemire Twp.
Eddy Bros.	1892-1916	N/A	Nicholas, Kamichisitit, Albanel, Varley, Jackson, and Casson Twps.
E.B. Foss	1901-	N/A	Jarvis and Anderson Twps.
U. T. McDougall Co.	1901-1903	3,537	Bertram and Latchford Twps.
Robt. Booth	1901-1902	5,895	Capreol Twp.
	1901-1902	9,432	Snider Twp.
	1901-1902	590	Creighton-Davies Twp.
	1901-1908	6,485	Hanmer Twp.
	1904-1905	23,580	Hutton Twp.
Tanner Brothers	1901-1905	44,802	Halifax and Tilton Twps.
W. W. Carter – Fesserton Lumber Co.	1901-1909	10,847	Laura, Tilton, and Halifax Twps.
The Saginaw Salt & Lumber Co.	1901-1906	N/A	Lefroy, Bolger, and Gillmor Twps.
	1901-1908	14,148	Foy Twp.
	1909-1910	88,425	Levack Twp.
The Ontario Lumber Co.	1901-1906	58,950	Norman Twp.
The Morgan Lumber Co.	1901-1910	157,986	Morgan Twp.
J. W. Munro & Son.	1901-1912	157,279	Harty, Leinster, and Hess Twps.
C. Beck Manufacturing Co.	1901-1905	35,842	Norman Twp.
	1901-1908	11,201	Rathbun Twp.
	1905-1909	80,644	McCarthy Twp.
	1908-1913	53,762	Creelman Twp.
	1913-1920	62,723	Bigelow Twp.
Victoria Harbour Lumber Co.	1901-1910	54,234	McCarthy Twp.
		54,234	Aylmer
		33,012	Mackelcan Twp.
		21,222	Scadding Twp.
		18,864	Rathbun Twp.
		1,179	Awrey Twp.
	1908-1926	165,060	Dieppe Twp.
		58,950	Caen Twp.
		45,981	Bevin Twp.
Morgan Lumber Co.	1901-1910	157,986	Morgan Twp.
The C. Beck Manufacturing Co.	1901-1918	N/A	Sudbury District and Shingwaukonce Twp.

Appendix 1. Cont.

Holland and Graves (later to be Graves and Bigwood)	1901-1902	16,506	Bowel Twp.
		17,685	Garson Twp.
		56,592	Capreol
	1901-1910	84,888	Cleland Twp.
		80,172	Lumsden Twp.
	1902-1903	47,160	Capreol Twp.
		29,475	Lumdsen Twp.
	1918-1922	9,432	Cleland Twp.
J.R. Booth	1901-1902	2,358	Laughrin Twp.
	1907-1914	N/A	Barber and James Twps.
	1915-1923	N/A	Banks, Wallis, and Roadhouse Twps.
	1923-1932	N/A	Powel, Baden, and Argyle Twps.
Geo. Gordon & Co.	1901-1950	45,745	Davis Twp.
	1902-1912	24,601	Appleby Twp.
	1902-1919	7,922	Awrey Twp.
	1902-1915	979	Hagar Twp.
	1903-1946	4,127	Scadding Twp.
	1903-1919	169,116	Kelly Twp.
	1904-1924	17,732	Hawley Twp.
	1904-1926	11,083	Burwash Twp.
	1906-1937	8,253	Bertram and Latchford Twps.
	1908-1932	81,469	McCarthy Twp.
	1909-1911	9,432	Hutton Twp.
	1923-1934	9,668	Hendrie Twp.
The Georgian Bay Lumber Co.	1902-1912	N/A	Jogues Twp.
N. N. Wright & Co. (later Loveland & Stone)	1902-1912	16,506	Hanmer Twp.
	1903-1907	39,497	Wisner Twp.
	1903-1911	28,296	Dowling Twp.
	1905-1913	28,296	Hutton Twp.
	1908-1911	11,790	Lockeyer Twp.
	1908-1912	28,296	Drury Twp.
The Canadian Copper Co.2	1902-1921	11,790	Snider, Creighton-Davies, Grahams, Parkin, Dowling, and Wisner Twps.
W. A. & G. P. Cockburn	1902-1905	N/A	Loudon, and Haddo Twps.
	1927-1929	2,358	Servos Twp.
	1924-1930	N/A	Hawley Twp.
Chew Bros.	1903-1911	35,370	Creighton-Davies and Graham Twps.
	1918-1947	124,974	Goschen, 67, Carlyle, and Humboldt Twps.
Miller and McCool	1904-1910	N/A	Whitman and Curtis Twps.
Parry Sound Lumber Co.	1905-1906	7,074	Street Twp.
Playfair & White	1905-1908	18,864	Dryden Twp.
	1907-1917	33,012	Parkin Twp.
Pine Lumber Co. (Devon Lumber Co.)	1905-1909	7,074	Cartier Twp.
	1909-1911	4,716	Borden Twp.
	1913-1920	14,148	Borden twp.
Booth and Shannon Company	1905-1927	129,690	Along the CPR between Biscotasing and Woman River (including Ramsey)
	1917-1920	4,716	Bigwood Twp.
The Northern Timber Co. (Onaping Lumber Co.)	1905-1907	14,148	Hendrie Twp.
	1905-1916	20,043	Hoskin Twp.
	1906-1907	2,948	Onaping Twp.
	1906-1910	22,991	Falconer Twp.
	1907-1918	11,790	Mason and Scollard Twps.
	1909-1910	10,611	Barnet Twp.
	1925-1928	4,716	Onaping Twp.
Echo Bay Lumber Co.	1906-1907	N/A	McMahon Twp.
Green & Co.	1907-1909	1,945	Hanmer, Capreol, Blezard, and Garson Twps.
The White Pine Lumber Co.	1907-1911	63,666	Gough Twp.

Appendix 1. Cont.

The Lovering Lumbering Co.	1907-1917	44,802	McKinnon Twp.
	1908-1909	2,358	Waters Twp.
Collins Inlet Lumber Co.	1907-1918	71,919	Goschen and Carlyle Twps.
Sharp and Jackson (later to become The Little Current Lumber Co.)	1907-1919	50,697	Berths 5 and 8, Humboldt, Moses and 82 and 90 Twps.
McFadden and Malloy	1907-1908	2,830	Harrow Twp. (by the Genty Lumber Co.)
	1908-1913	116,721	Shibananing Twp.
	1913-1917	81,351	Gough Twp.
	1916-1920	64,845	Poulin Twp.
	1917-1920	11,201	Sagard Twp.
The Spanish river Lumber Co.	1907-1920	329,648	Baldwin, Shakespeare, Hallam, Tennyson, Salter Boon, Cadeau, and Gerow Twps.
	1914-1923	106,110	Prescott (I), Monestime (J), Foucault (K), Plourde (M), Lefebvre (N), and Fontaine (O) Twps.
	1915-1917	5,895	Solski Twp.
	1919-1920	2,948	Ouellette Twp.
W. C. Cochrane	1907-1909	3,537	Garson Twp.
	1907-1909	4,716	Capreol Twp.
	1909-1910	2,358	Wisner Twp.
	1910-1921	56,592	Cascaden Twp.
	1915-1919	10,611	Sweeny Twp.
	1918-1928	1,179	Noble Twp.
Graves and Bigwood	1907-1925	219,294	Vernon Twp.
		115,542	Porter and Totten Twps.
		96,678	Berth 91
		47,160	Ermatinger Twp.
		4,716	Hyman Twp.
Craig Brothers and Timagami Timber	1907-1932	N/A	Haultain and Nicol Twps.
The Midland Lumber Co.	1908-1911	N/A	North half of Hembruff Twp.
Playfair & White	1908-1911	N/A	South half of Hembruff Twp.
The Carney Lumber Co.	1908-1912	49,518	Mandamin, Strain, and Teasdale Twps.
W.F. Monroe Co.	1908-1913	N/A	South of Gillmor and Kane Twps.
The Wolverine Cedar and Lumber Co.	1908-1913	141,480	Dunlop and Weeks Twps.
The Georgian Bay Lumber Co.	1908-1913	24,759	Mackelcan Twp.
	1908-1916	73,098	Aylmer Twp.
Wm. McVicor & Sons	1908-1919	2,358	Berth 11
The Frazer Lumber Co.	1908-1923	N/A	Morin Twp.
The Spanish Mills Co.	1908-1927	135,113	Rutherford Twp.
	1915-1932	141,480	Valin, Haentschel, Leask, Cotton, and Grigg Twps.
	1916-1924	31,833	Rowat, Oshell, and Hotte Twps.
The Hope Lumber Co.	1908-1910	24,759	Merrit Twp.
	1914-1920	120,258	Sayer and Le Caron Twps.
	1920-	N/A	Le Caron, Slievert, Simons, Wardle, Snow, Reilly, Gaudry, and Hurlburt Twps.
The Clevland and Sarnia Saw Mill Co.	1908-1913	73,098	Foster Twp.
	1924-1925	43,623	Craig Twp, Bolck "A", and "Z"
Andrew Tait	1909-1911	15,327	Weeks Twp.
The Rosedale Saw Mills Co.	1909-1912	6,131	Creelman Twp.
Allan McPherson	1909-1910	5,895	Hutton Twp.
	1918-1919	1,179	Lorne Twp.
Wm. Milne & Sons	1909-1916	21,222	Harrow Twp.
	1909-1918	25,938	Kitchener Twp.
	1909-1912, 1918-1919	17,685	Roberts Twp.

Appendix 1. Cont.

W.F. Cashon Co.	1909-1914	N/A	Albanel Twp.
Rixon, Ansley & Stoddart (later to become Hocken Lumber and then The Hocken Manufacturers Ltd.)	1909-1912	10,611	Berth 12
	1915-1948	32,894	Berth 12, Poster and McKinnon Twps., Islands 1555, 1701, Wardrope Island and East, West and Middle Sampson Island
Waldie Bros.	1910-	N/A	Lockeyer, Gunterman, Bouck, Bolger, Beange, and Raimbault Twps.
The Cutler Bay Lumber Co. (Loveland & Stone)	1910-1912	4,716	Hutton Twp.
Barnett and Allen	1911-1912	2,948	Tofflemire Twp.
Foley Bros.	1911-1914	35,370	Hennessy and Garvey Twps.
	1912-1914	15,917	Frechette Twp.
The Union Lumber Co.	1912-1913	3,537	Hutton Twp.
Eddy & Glen	1912-1916	N/A	Chesley and Anderson Twps.
Keenan Brothers	1913-1924	22,401	McGregor Island
T.N. Desmarais	1913-1946	4,716	Cherriman, Falconer (1926), and Scollard (1929) Twps.
The Diamond Match Co.	1914-1915	4,127	Hutton Twp.
		3,537	Parkin Twp.
Manley Chew (later to be owned by Manson Lumber Co. and then by Midland Lumber Co.)	1914-1930	84,888	Fraleck Twp.
		36,077	Telfer Twp.
		27,589	Grigg Twp.
		12,969	Howey Twp.
	1916-1919	4,716	Dill and Secord Twps.
The Marshay Lumber Co.	1914-1939	130,869	Marshay (1914), Marhsay, Beulah, Blewett, Shelley, Frechette, Garvey, Hennessy, Sweeny, McNamara, Beaumont, and Moffat (1917) Twps.
Hale & Bell	1915-1919	141	Nairn Twp.
The Eastern Lands Dept.	1916-1917	17,096	Ivanhoe and Foleyet Twps.
Grier & Herron Lumber Co.	1916-1927	22,404	Twp.113
S. L. Lambert	1917-1921	6,485	Sweeny Twp.
	1930-1931	1,179	Fraleck, Telfer, Grigg, and Howey Twps.
Height and Dickson	1918-1926	N/A	Wigle Twp.
The Anglo Canadian Construction Co.	1918-1926	766	Wigle Twp.
Harris Tie & Timber Co.	1918-1935	8,076	Whalen, Middleboro, and Jack Twps.
	1926-1926	6,485	Somme, Chester, and Neville Twps.
	1929-1930	3,773	Benneweiss Twp.
	1923	2,358	Jack and Carter Twps.
The Field Lumber Co.	1918-1921	1,238	Hutton Twp.
	1937-1947	2,358	Loughrin Twp.
McCaffrey & Berry	1919-1921	2,358	McLennan Twp.
Boivin Tie & Timber Co. (Later to become The Triangle Lumber Co.)	1919-1925	2,358	Belford Twp.
James McCreary Jr.	1919-1935	N/A	Carter Twp.
The R.B Herron Lumber Co.	1920-1923	1,415	Penhorwood and Hardiman Twps.
Marshay Lumber Co.	1920-1928	2,358	Groves Twp.
W.C. Cochrane	1920-1928	8,253	St-Louis Twp.
The Pembroke Tie and Timber Co.	1920-1930	2,948	Champagne Twp.
The McNaught Lumber Co. (later to become Wakami Lumber Co.)	1920-1926	4,716	McNaught and Gallagher Twps.
	1927-1931	17,685	Twps. 10A, 11B, 9A, 10A
	1933-1946	63,666	Twps. 10A, 11B, 9A, 10A
Continental Wood Products (later to become D. A. Clark & C. B. Devlin)	1923-1927	5,895	Sherlock, Kapuskasing, Lougheed, Ossin, Borden, Gamey and Lackner Twps.
	1934-1937	271	Sherlock, Kapuskasing, Lougheed, Ossin, Borden, Gamey and Lackner Twps.

Appendix 2. Select mills that were processing white pine in MNR's Northeast Region circa 1962 (ODLF 1967).

Sawmill	Location	Volume (m^3 yr^{-1})
Lahaie Allan	Alban	N/A
Fielding Lumber Co.	Gatchell	> 2,360
L.A. Lachapelle	Estaire	N/A
Macworth Timber Company	Cockburn Island	N/A
Pineland Timber Co.	Sudbury	> 2,360
W.B. Plaunt & Son	Sudbury	> 2,360
Portelance Lumber Ltd.	Capreol	> 2,360
Valley Crest Construction	Sudbury	1,180 to 2,360
Ward Ednie Lumber	Manitowaning	1,180 to 2,360
JJ. McFadden Lumber Co. Ltd.[42]	Blind River	94,320
Austin Lumber (Dalton) Ltd.	Chapleau	> 2,360
Sheppard & Morse Ltd.	Chapleau	> 2, 360
Mount Joy Timber Co. Ltd.	Gogama	> 2,360
Pineland Timber Co.[43]	Sudbury	> 2,360
A.E. Wicks Ltd. [44]	Cochrane	> 2,360
Wesmark Lumber Co. [45]	Sudbury	> 2,360

[42] ODLF 1965
[43] Although these mills were located outside the districts, they were procuring wood from them
[44] Ibid
[45] Ibid

Appendix 3. Average volume of roundwood white pine and red pine manufactured between 1999 and 2005 in facilities located in MNR's Northeast Region.[96]

Facility	Location	Volume ($m^3\ yr^{-1}$)	Facility	Location	Volume ($m^3\ yr^{-1}$)
Goulard Lbr.	Sturgeon Falls	48,331	Mainville Lbr.	Chelmsford	1,125
Tembec	Mattawa	43,458	Devon Mills Ltd.	Chapleau	892
R.Fryer For. Prod.	Monetville	41,098	Gervais For. Prod.	Falconbridge	393
Midway Lbr. Mills	Thessalon	38,420	Adrian Fauteux	Blind River	379
Lahaie Lbr.	Alban	18,936	Portelance Lbr.	Capreol	361
H&R Chartrand	Noelville	15,368	High Falls Lbr.	Wawa	189
Pineal Lake Lbr.	Chapleau	11,154	Little John Ent.	Timmins	124
Forest Ply. Ind.	Blind River	10,957	R&A Hako-Oja	Wahnapitae	85
Isidore Roy Ltd.	Hagar	10,432	Don Connors	Kenabeek	51
Grant For. Prod.	Englehart	4,947	Elliott Lbr.	Goulais R.	21
Boniferro M.W.	Sault Ste.Marie	3,492	John Tynela	Matheson	20
Cheminis Lbr.	Kearns	1,812			

*Data from eFAR, MNR's electronic facility annual return database; excludes the red pine class (see Figure 19).

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(0.3k P.R., 08 11 30)
ISBN 978-1-4249-7011-1 (print)
ISBN 978-1-4249-7012-4 (pdf)